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ABSTRACT

The project on Scope Sequence and Coordination of Secondary School Science (SS&C) was initiated by the National Science Teachers Association (NSTA) and recommends that all students study science every year and advocates carefully sequenced, well-coordinated instruction in biology, chemistry, earth/space science, and physics. This document represents a collaborative effort between the NSTA, the American Petroleum Institute (API), the California SS&C Project, and the Texas SS&C Project. These materials were developed through a brainstorming process that included industrial scientists, science teachers from different SS&C sites, and science educators. This book is divided into 3 sections. Section I, SS&C Overview, includes a description of the projects and a K-12 sequence of SS&C science. Section II, Texas SS&C Materials, includes the following: overview, environment, fueling around, and a materials list. Section III, California SS&C Materials, includes: overview, offshore oil drilling, petroleum in our daily lives, oil exploration, oil extraction, and environment, and an appendix. (JRH)

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A PUBLICATION OF THE NATIONAL SCIENCE TEACHERS ASSOCIATION

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A PROJECT ON SCOPE, SEQUENCE, AND COORDINATION OF SECONDARY SCHOOL SCIENCE

Middle Level SS&C

Energy Series

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This volume represents a collaborative effort between the National Science Teachers Association, the American Petroleum Institute, the California SS&C Project, and the Texas SS&C Project. To bring these materials together successfully, the assistance of Deborah Ausman, editorial coordinator for the Texas SS&C Project, was absolutely essential. All of these materials were initially developed through a unique brainstorming process. Brainstorming teams included industrial scientists, science teachers from different SS&C sites, and science educators. Members included:

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Linda W. Crow, Project Director

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PROJECT ON THE SCOPE, SEQUENCE, AND COORDINATION OF SECONDARY SCHOOL SCIENCE

The project on Scope Sequence and Coordination of Secondary School Science (SS&C), was initiated by the National Science Teachers Association. It represents a major reform effort to restructure science at the secondary level.

This reform recommends that all students study science every year and advocates carefully sequenced, well-coordinated instruction in biology, chemistry, earth/space science, and physics. Secondary schools have traditionally used a "layer cake" curriculum that teaches science as year-long, discrete, and compressed disciplines. In contrast, SS&C spaces the study of each of the sciences over several years. Research on the spacing effect indicates that students can learn and retain new material better if they study it in spaced intervals rather than all at once.[1]

In addition, SS&C emphasizes appropriate sequencing of instruction, taking into account how students learn. In science, understanding begins with concrete experiences that can be given names or symbols later.[2-3] Practical applications of science should focus on a personal level in seventh grade and become more global in later grades. These personal and societal applications will allow students to make sense of science and see its relevance. As students develop, they will be able to generalize these concrete, direct experiences to form abstractions and theories. With a sequenced approach, students will no longer be expected to memorize facts and information mindlessly. Instead, they will acquire a depth of understanding.

SS&C provides this understanding of science to all students.[4] Truly gifted students will not be overlooked, but will instead help the rest of the class to grow and become more diverse. Our current sophisticated filtering system does not allow most students to continue science education beyond one or two years of secondary school. We must stop this filtering process, because science is needed not just by prospective scientists and engineers, but also by the scientifically literate citizens of the future. All students must be given the opportunity to learn several sciences over several years. The SS&C reform movement begins this process.

References

1. Dempster, F. (1988). The spacing effect: A case study in the failure to apply the results of psychological research. *American Psychologist, 43*, 627-634.
2. Linn, M. C. (1986). Science. In R. F. Dillon & R. J. Sternberg (Eds.), *Cognition and instruction.* (pp. 155-204). Orlando, FL: Academic Press.
3. Piaget, Jean. (1973). *To understand is to invent: The future of education.* New York: Grossman Publishers.
4. The Action Council on Minority Education. (1990). *Education that works: An action plan for education of minorities.* Massachusetts Institute of Technology, Cambridge, Massachusetts.

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A Joint Project with the American Petroleum Institute

TEXAS SS&C PROJECT

The Houston Project on Scope, Sequence, and Coordination (SS&C) has been part of the NSTA's reform efforts since 1989. Science educator Linda Crow spearheaded the move to initiate a reform effort in Houston, and has managed the project ever since, with the support of the Houston Independent School District and the Baylor College of Medicine.

Houston is a fertile ground for education reform. The need for a scientifically literate population is everywhere apparent. Houston is the site of the Texas Medical Center, a massive complex of 41 educational institutions, research and patient-care facilities, and hospitals. Houston is also a center for the petrochemical industry, and the site of NASA's Johnson Space Center. Moreover, the implications of the country's swiftly changing demographics on education are suggested nowhere better than Houston, home of the nation's fifth largest school district. A reform that works in Houston holds promise for school systems, large and small, throughout the United States.

Project staff, teachers, university educators, and scientists from throughout the Houston area and across the United States participate in the program's development, thereby providing a depth and breadth of knowledge and experience. The developmental process is a dynamic one, with numerous opportunities for program improvement. At the same time, the project is structured to encourage steady and orderly growth.

Restructuring Science Education in California

California is one of six national SS&C sites. In California, SS&C is a grassroots effort directly aligned with the California Science Framework. Since its inception in early 1989, the California SS&C Project has grown to over 200 participating secondary schools. Approximately 600 teachers are supported through the project, which impacts over 40,000 students.

Why is Science Reform Needed?

It has been documented that schools in the United States are not educating students about a world that increasingly depends on sophisticated and rapidly changing science and technology. Most students leave high school without a basic understanding of science, mathematics, or technology. Our education system is not providing its future citizens with the scientific knowledge necessary to make informed decisions affecting their lives and the world.

In all other industrialized nations, students study different science subjects over several years. Only the United States isolates the science disciplines, teaching biology, chemistry, earth/space science, and physics in discrete, year-long segments. With this layer cake curriculum, students in the United States rarely develop an interest in science and cannot see how the sciences interrelate with each other and human concerns.

Students perceive their traditional textbook-driven science subjects as difficult, boring, and irrelevant. Many opt out of science courses as soon as the system allows. Over 50 percent of students will not take another science course after the tenth grade. In California, less than 40 percent of students take a course in chemistry, and only 13 percent enroll in physics.

What Can SS&C Do For Science Education?

- Create more scientifically literate citizens
- Increase the number of students, especially females and minorities, studying science
- Deepen students' understanding of scientific concepts
- Provide alternative methods and improved tools for assessing student learning
- Enable students to relate and apply their science education to the world around them

AMERICAN PETROLEUM INSTITUTE

The American Petroleum Institute (API) is the United States petroleum industry's primary trade association. API has some 300 member companies engaged in all aspects of the energy business. They find, produce, and process crude oil and natural gas, bringing gasoline and other petroleum products to service stations, stores, and households nationwide. On behalf of its members, API acts as a center for research on energy, economic, and environmental matters; an industry resource for technical information and support; and an advocate in state and national policy debates.

API and SS&C

API has entered into a partnership with the National Science Teachers Association (NSTA) to help improve science education nationwide. With the support of API funding, the NSTA has produced a variety of materials, such as the *Middle Level Energy Series*, to help teachers educate their students about energy production and consumption. API also participates directly in the development of these materials. Scientists and engineers from API member companies and the petroleum industry work with SS&C teachers to decide the issues each block should cover and the best activities to engage these issues. These scientists ensure that the science covered in each unit reflects the latest industrial techniques and applications, so that students see that science is an active, evolving, and useful discipline.

API believes that the SS&C approach to teaching science will lead to a better educated citizenry and a better informed workforce, which will make American business and our nation in general more competitive in the global community. Because the petroleum industry comprises scientists—geologists, chemists, geophysicists, and engineers, to name a few—we want more young men and women to choose scientific careers. For these reasons, API's members, as parents and conscientious business men and women, care about and want to encourage education reform.

SS&C PROJECT
THE PROCESSES OF SCIENCE

by Arnold Arons, University of Washington*

OBSERVING	Examining a system (or monitoring its change) closely and intently through direct sense perception to notice aspects not readily apparent from casual scrutiny.
INFERRING	Reasoning, deducing, or drawing conclusions from given facts or from evidence, such as that provided by observation.[1]
MEASURING	Using instruments to determine quantitative properties of the objects, systems, or phenomena.
COMMUNICATING	Conveying information, insights, explanations, results, or inferences to others. Communication can be verbal, pictorial, graphic, or symbolic, invoked separately or in combination.
CLASSIFYING	Systematic grouping of objects or systems into categories based on shared characteristics established by observation.
PREDICTING	Foretelling or forecasting outcomes when changes occur in a system. Scientific predictions are not random guesses or vague prophecies but involve logical inferences and deductions based on the natural laws, principles, models, or theories that govern the behavior of the system, or on extensions of empirical data applicable to the system.
CONTROLLING VARIABLES	Holding all variables constant except the one under investigation to establish whether an unambiguous causal relationship exists.
INTERPRETING DATA	Translating or elucidating in intelligible and familiar language the significance or meaning of data and observations.
DEVELOPING MODELS	Using evidence drawn from observation and measurement to create a mental picture of a phenomenon (e.g. current in an electric circuit). Scientists use models to rationalize observed effects and to predict how systems will react to changing conditions.

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*Dr. Arons prepared these descriptions specifically for this block.

[1] Note on usage: The word "infer" is often confused with "imply" in poor writing and speech. The word "imply" means to hint, intimate, or state indirectly. The two definitions are not interchangeable, and their distinction should be carefully preserved in good English usage.

SS&C PROJECT
THE PRODUCTS OF SCIENCE

by Bill G. Aldridge, National Science Teachers Association

SCIENTIFIC TERM	A word or words that scientists use to name an entity, object, event, time period, classification category, organism, or part of an organism. Terms are used for communication and do not normally include names given to concepts, laws, models, or theories.
SCIENTIFIC FACT	An observation, measurement, conclusion drawn from evidence, or summary statement, made about a natural phenomenon, event, or property of a substance. Facts have been recognized as such by the relevant scientific profession after results have been replicated consistently.
SCIENTIFIC CONCEPT	Regularly occurring natural phenomena, properties, or characteristics of matter that are observable or detectable in many different contexts, and can be defined as natural relationships or mathematical equations. Basic scientific concepts, such as distance, mass, electric charge, and time, are fundamental to explaining how nature works. Most scientific concepts are derived from basic concepts. Examples of mathematically derived concepts include the definitions for density, speed, velocity, and acceleration.
SCIENTIFIC PRINCIPLE	A generalization or summary expressed as a statement or mathematical equation that explains a relationship between measurements or variables. Scientific principles express significant generalizations that are not general enough or applicable enough to be considered scientific laws.
EMPIRICAL LAW	An empirical law expresses a relationship that has been established between two or more concepts through observation or measurement, but that relies on no theory or model for its expression or understanding. Such laws typically serve as cornerstones for theories or models. Examples include Snell's Law of Refraction, Kepler's Laws, and evolution.
SCIENTIFIC THEORY	A verbal or mathematical statement that describes one or more types of observations, measurements, principles, or empirical laws, and predicts events not implied directly by any of the evidence. Like facts, theories must be replicable in different contexts. Scientists generally accept those theories that are simple, comprehensive, and accommodating. Alternative theories that merely

	explain existing laws without making new predictions, or do not offer concise and easliy applicable explanations are less useful to scientists. Examples of powerful theories include atomic theory, kinetic molecular theory, theory of natural selection, the theory of plate tectonics, or quantum theory.
SCIENTIFIC MODEL	A visual, verbal, or mathematical representation that helps explain and describe scientific phenomena, theories, laws, physical entities, organisms, or parts of organisms. Examples of models include wave models, particle models, electric current models, and the greenhouse model of the earth's atmosphere.
UNIVERSAL LAW	A scientific law that scientists universally accept and is universally applicable. Universal laws are few, but are basic to all scientific disciplines. They include the Law of Universal Gravitation, Coulomb's Law, the Law of Conservation of Energy, and the Law of Conservation of Momentum.
SCIENTIFIC APPLICATION	The product developed when scientists use the results, measurements, empirical evidence, or predictions derived from scientific experimentation to design machines or provide new functionality of human design. Some applications depend on several laws or theories, and, historically, many have been devised or produced without prior knowledge of the specific theories or laws.

SS&C PROJECT
K-12 SEQUENCE OF SS&C SCIENCE

Basic Components of the Natural Sciences

Certain processes and resulting products are common to all the natural sciences. The processes that your students will begin to master during the course of the *Middle Level Energy Series* include observing, classifying, measuring, interpreting data, inferring, communicating, hypothesizing, developing models and theories, and predicting. By going through these processes, your students will produce terms, facts, concepts, principles, empirical laws, theories, and applications, the instruments and tools of science. While the processes listed above are not unique to the natural sciences, many of the products are. In order for a product of science to be considered a basic component of all the natural sciences, it must transcend subject area and discipline to encompass all the major subject areas associated with natural science, including biology, chemistry, earth/space science, and physics.

Basic Terms Common to All Natural Sciences

There are very few terms that are basic components of natural science, but some common terms include:

- Multiples associated with the prefixes nano, micro, milli, centi, kilo, mega, and giga.
- Names of units of time, mass length, area, and volume.
- Names of SI derived units for force, electric charge, pressure, magnetic field, work, energy, and power.

Basic Facts Common to All Natural Sciences

Certain basic science facts are common to all the natural sciences. These facts are usually operational definitions, measurements, or observations that can be replicated. Rather than simply asking students to memorize these facts, help them to understand the underlying concepts that support each fact and show them where to locate the fact in reference material. We have listed some of the most important basic natural science facts, along with the grade levels where they are first encountered, below. Keep in mind that the level of abstraction or the degree to which the fact is made quantitative increases with grade level, so that fundamental facts are continually reinforced in a spiral fashion.

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SS&C PROJECT
K-12 SEQUENCE OF SS&C SCIENCE (CONT.)

Grades 6-8

Definition of an inch in centimeters

Speed of light in a vacuum

Value of absolute zero on the Celsius temperature scale

Density of liquid water

Boiling point of water (two significant figures)

Freezing point of water (two sig. fig.)

Speed of sound in air (two sig. fig.)

Speed of sound in water (two sig. fig.)

Definitions of minute, day, hour, and year

Names of common acids and bases

Names of common elements that are electrical insulators

Names of common elements that conduct electricity

Grades 9-10

Wavelengths in nanometers of visible colors of light (two sig. figs.)

Approximate range of wavelengths in nanometers of ultraviolet and infrared radiation (two sig. fig.)

Refractive index for glass and for water (two sig. fig.)

Components of simple, diatomic molecules of common gases and common compounds (numbers of atoms and molecular mass)

Numerical value of one mole

Volume of one mole of a gas at STP

Definition of one atomic mass unit

Atomic numbers and atomic masses in grams per mole for oxygen, nitrogen, carbon, and hydrogen

Approximate dimensions of inorganic molecules

Components of common atoms and isotopes (allottment of protons and neutrons in nucleus and electrons surrounding nucleus)

Value of one calorie in joules

Heat capacity of water

Latent heat of vaporization of water

Latent heat of fusion of water

Value of acceleration due to gravity on earth (two sig. fig.)

Definition of a pound in newtons

Atmospheric pressure on earth (2 sig. fig.)

Approximate radii of the earth, moon, and sun

Grades 11-12

Definition of an electron-volt in joules

Definitions of simple, face-centered, and body centered cubic crystal structures

Permittivity and permeability of free space

Half-life of carbon-14

Charges of common free element ions, in units of electron charge

Value of Planck's constant

Definition for the constant, k, in Coulomb's law of force for electric charges

Value of the constant, G, in the law of universal gravitation

Value of the ideal gas constant, R

Approximate radii of an atom and an atomic nucleus

Approximate range of sizes of various kinds of organic molecules

Boltzmann's constant

Mass and charge of an electron, proton, and neutron

Values of mass-energy equivalence

SS&C PROJECT
K-12 SEQUENCE OF SS&C SCIENCE (CONT.)

Basic Concepts Common to All Natural Sciences

Many basic concepts of the natural sciences transcend subject fields or disciplines. For example, the list of concepts below appears to emphasize primarily phsyics. Keep in mind, however, that physics informs chemistry, and that both these subjects inform the life sciences and earth/space science. Students encounter the common basic concepts listed below at all levels of science education. In earlier years, students learn qualitative and descriptive definitions of the concepts. In later years, they can begin to understand abstractions of the concepts, along with quantitative defintions.

Grades K-5

- Distance
- Depth
- Length
- Width
- Height
- Perimeter
- Circumference
- Angle
- Solid
- Weight
- Liquid
- Conservation

Grades 6-8

- Scalar (a number and a unit)
- Precision (and significant figures)
- Accuracy (and calibration against a standard)
- Exponent
- Power of ten and order of magnitude
- Continuity and discontinuity
- Length, area, volume, mass, electric charge, and time
- Surface area
- Mass density
- Time rate of change with distance (speed)
- Time rate of change with speed (acceleration)
- Time rates of change in general
- Velocity (speed and direction)
- Force
- Pressure
- Buoyancy
- Work
- Energy
- Power
- Kinetic energy (translational and rotational)
- Potential energy (gravitational, electrical, and nuclear)
- Pulse
- Wave (monochromatic)
- Wavelength
- Amplitude
- Superposition of waves
- Diffraction
- Interference
- Spectrum
- Reflection
- Refraction
- Dispersion
- Period
- Periodic motion
- Simple harmonic motion
- Equilibrium
- Thermal equilibrium
- Temperature
- Heat
- Thermal energy
- Freezing point
- Boiling point
- Conductivity
- Concentration
- Mixture
- Homogeneous
- Element
- Compound
- Solvent and solute
- Acid
- Base
- Crystal
- Gas

SS&C PROJECT
K-12 SEQUENCE OF SS&C SCIENCE (CONT.)

Grades 9-10

- Vector (a number, a unit, and a direction)
- Power
- Atom
- Molar volume
- Molecule
- Atomic number
- Mole
- Atomic mass
- Nucleus
- Heat capacity
- Isothermal
- Catalysis
- Colloid
- Current (mass, charge or volume per unit of time)
- Distance rates of change (contours and gradients)
- Evolution
- Centripetal
- Gravity
- Invariance
- Longitudinal wave
- Linear momentum
- Angular momentum
- Osmosis
- pH
- Radioactivity
- Resonance
- Electric field
- Magnetic field
- Transverse Wave
- Electromagnetic Wave
- Monochromatic
- Intensity

Grades 11-12

- Displacement (distance and direction)
- Intensity
- Vector acceleration
- Wave velocity
- Polarization of waves
- Coherence (temporal and spatial)
- Ion
- Charge density
- Torque
- Electric dipole
- Adiabatic
- Internal energy
- Enthalpy
- Entropy
- Density (distribution function)
- Latent heat of fusion
- Latent heat of vaporization
- Chemical potential energy
- Elastic potential energy
- Fission
- Fusion
- Half-Life
- Isotope
- Photon
- Plasma
- Simultaneity
- Relativity

Basic Empirical Laws Common to All Natural Sciences

Following is a list of the empirical laws that students of natural science will encounter, along with the grade level where the laws will be introduced.

Grades 6-8

- Pascal's Law
- Boyle's Law
- Charles' Law
- Gay-Lussac Law
- Law of Specular Reflection
- Law of Conservation of Energy
- Evolution (observed patterns of change over time

SS&C PROJECT
K-12 SEQUENCE OF SS&C SCIENCE (CONT.)

Grades 9-10

Law of limiting factors
Photosynthesis (as a process)
Graham's Law
Chemical Periodicity
Newton's three Laws of Motion
Observed variation of strength with linear dimension change
Inverse Square Law
Ampere's Law
Coulomb's Law
Faraday's Law
Gauss's Law
Snell's Law of Refraction
Doppler Effect
Observed variation of mass with linear dimension changes
Observed variation of surface area with linear dimension changes

Grades 11-12

Le Chatelier's Principle
Hess's Law
Dalton's Law of Partial Pressure
Law of Universal Gravitation
Law of Conservation of Momentum
Observed variation of heat through a surface with linear dimension change
Wien Displacement Law
Fourth Power Law of Radiation

Theories and Models Common to All Natural Sciences

Theories are tentative, and even the most recent theories represent merely one stage in a continuous process. Unlike facts, observations, and empirical laws, which summarize data, measurements, or observations, theories are creative constructs that do not necessarily map one-to-one with reality. In fact, many alternative theories can explain the same set of phenomena. Consequently, scientists generally accept those theories that are simple, comprehensive, and accommodating. Alternative theories that merely explain existing laws without making new predictions, or do not offer concise and easily applicable explanations are less useful to scientists.

Theories make predictions, but are never proved. Rather, a theory's predictions can lead scientists to develop a new empirical law to corroborate the theory. This empirical law will stand solid until the results it predicts can no longer be replicated.

Theories, more than any other expression in science, can be described in abstract ways. Theories may be learned at a very descriptive level, later at a somewhat more symbolic level, and so forth, until one applies the theory together with sophisticated mathematics. Below are some theories that natural science students will encounter at different grade levels.

Grades 6-8

Wave theory of light

Grades 9-10

Theory of scaling laws (surface area, volume, and mass)

Theory of the chemical bond (from early theories of atoms and molecules resulting from laws of definite and multiple proportions to theories associated with various kinds of chemical bonds)

Atomic theory (from sequence of Thomson, Rutherford, and Bohr models)

Grades 11-12

Theory of scaling laws (periodicity, heat transfer through surfaces and strength)

Kinetic-Molecular theory (as explanation of relationship of temperature to average kinetic energy of molecules)

Electromagnetic theory (as synthesis of empirical laws of Ampere, Faraday, and Gauss, with new prediction on speed of waves, with connection to light and confirmation by Hertz)

Theory of heat (internal energy, first law as semi-empirical; second law as theory, following use of postulates and mathematical reasoning)

Particle (photon) theory of light

Quantum theory (atomic and nuclear, including orbitals, quantum numbers)

The modern periodic table (from theory, including Pauli Exclusion Principle)

The modern theory of solids (include elements of solid state physics as it applies to crystals, metals, and semiconductors)

Cosmology and theories of evolution (explanations of general evolutionary change)

Applications of Basic Science Concepts, Empirical Laws, and Theories

In a very real sense, the life and earth sciences are natural applications of fundamental concepts, principles, and laws of science. But these fundamental principles can also be used to create human-made devices that provide services for the arts, manufacturing, transportation, and the home.

Certainly one important application of the life and earth sciences is in social policy making. Although the life and earth sciences underlie many personal and societal problems, natural science teachers should make an effort to teach science rather than social studies. While it may be appropriate to encourage students to examine science from an interdisciplinary perspective or to study the science associated with serious social, political, economical, philosophical, or religious issues, social action or decision making should be left to other courses.

Since basic concepts can be approached from a qualitative, descriptive level and later at a quantitative, more abstract level, the sequencing problem is not at all formidable. During the middle grades, for example, the same teacher can teach the basic sciences along with more specific units, such as life and earth sciences. By high school, where the levels of quantitative or abstract treatments are higher, specialists will probably need to work as a coordinated team.

Grades K-5

At the elementary school levels, students consider concepts, gaining experience with their application in a variety of contexts. They also develop process skills by observing interactions, creating and testing hypotheses, offering descriptive explanations for observations, and building primitive theories. The major problem at this level is the tendency of teachers and, especially, textbooks to offer only modern "correct" theories or explanations, rather than allowing student developed explanations to stand whenever students no longer have the resources necessary to test particular hypotheses. Asking students how they know what they know can be a better way to encourage learning. K-5 students should acquire a repertoire of experience with the daily, monthly, and annual positions of the earth, sun, and moon, with some ability to describe what they are likely to see in the locations and appearance of these objects. They might also begin to see patterns in the stars, and notice changes in those patterns over a year. Finally, give your students experience observing simple substances and living organisms.

Grades 6-12

At this level, students can gain additional experience with a wider range of science phenomena, develop numerous empirical laws from experimental evidence, and construct hypotheses and theories to explain the phenomena and laws they have found. Process skills should be well-developed by eighth grade, and experimental procedure thoroughly understood. As in the K-5 levels, texts and teachers at this level still have a tendency to emphasize modern explanations and theories, and to discount the limited explanations or theories developed by students. Teachers should continue to encourage student theories, offering the "correct" explanation as another possibility that students can compare with their own observations. Below are some suggested topics to focus on in high school science courses.

NINTH GRADE SCIENCES

Ninth Grade Chemistry

- Solutions
- Enzymes/Catalysts
- Types of reactions
- Equilibria I (vaporization, condensation, dissolution & precipitation)
- Simple Stoichiometry

Ninth Grade Biology

- Organismal Biology
  - photosynthesis: (observational evidence)
  - respiration: (substrate utilization/digestion)
- Mendelian Genetics I
  - Principles
  - Use of probability

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A Joint Project with the American Petroleum Institute

- Adaptations (evidence of evolution)
- Response to environment (evidence of evolution)
- The optical magnifier and microscope

Ninth Grade Earth/Space Science

Geology
- Soils
- Mapping
- Contours
- Fuels

Oceanography
- Ocean and Weather

Astronomy
- The refracting telescope
- Stars (patterns)
- Measurements by parallax
- Measurements by Inverse Square Law of Light

Meteorology
- Weather instruments
- Weather
- Air Masses
- Climate

Ninth Grade Physics
- Rockets and trajectories
- Machines
- Simple calorimetry
- Thermal insulation

TENTH GRADE SCIENCE

Tenth Grade Chemistry
- pH meter
- Types of chemical bonds
- Oxidation/Reduction
- Gas reactions
- Molar calculations
- Common crystals

Tenth Grade Biology
- Centrifuge
- Simple chromatography
- Liebig's Law extended
- Cellular biology (Cell structure and function)
- Genetics II
  - Extensions
  - Exceptions
- Chromosomes, etc.
  - Mitosis
  - Meiosis
  - Sutton-Boveri, Bridges
- Genetic versus environmental variation (evidence of evolution)

Tenth Grade Earth/Space Science

Geology
- Faults, stresses, folding – deformations
- Earthquakes
- Uniformity

Oceanography
- Sonar devices
- Tides
- Marine habitats
- Ocean circulation
- Coriolis effects

Astronomy
- Planetary features and detection

Meteorology
- Condensation and Precipitation
- Heat transfer
- Global circulation

Tenth Grade Physics
- Thermal expansion
- Sound waves and resonance
- Doppler Effect
- Single lens and reflector optics
- Simple electric circuits

ELEVENTH GRADE SCIENCE

Eleventh Grade Chemistry
- Spectrophotometer
- Electro-chemistry, half-cells, and Redox
- Chemistry of carbon
- Natural polymers (carbohydrates, lipids, proteins)

Eleventh Grade Biology
- Phase contrast microscope
- Cellular Biology
  - Photosynthesis: Hill Reaction
  - Respiration: Glycolysis, fermentation
- Biochemical genetics

- One gene = one enzyme
- Mutation (evidence of evolution)
- Populations
  - Structure
  - Dynamics, e.g., Hardy Weinberg, genetic drift

Eleventh Grade Earth/Space Science

Geology
- Landform
- Evolution (geological changes)
- Coastal processes

Oceanography
- Changing levels of the coastal region
- Glaciation

Astronomy
- Meteorites
- Asteroids

Meteorology
- Storms – Hurricanes and tornadoes
- Optical phenomena of the atmosphere – rainbows, mirages, halos

Eleventh Grade Physics
- AC electric circuits
- Batteries
- Motors and generators
- Meters
- Optical instruments
- Prisms and diffraction gratings

TWELFTH GRADE SCIENCE

Twelfth Grade Chemistry
- Biochemistry (enzymes, biosynthesis)
- Equilibria II (reaction rates)
- Polymers, artificial

Twelfth Grade Biology
- Electron microscope
- Molecular biology
  - Photosynthesis: (carbon dioxide fixation light dark reaction; Calvin-Benson cycles)
  - Respiration: (Kreb's Cycle)
- Molecular genetics
  - Structure of DNA
  - Central dogma
  - Recombinant DNA
- Theories of evolution before Darwin
  - Natural selection
  - Mechanisms
  - Speciation
  - Extinction

Twelfth Grade Earth/Space Sciences

Geology
- Theory of Plate Tectonics
- Nuclear counting technology
- Radioactive dating
- Landform evolution
- Coastal processes
- Earth interior
- Bowen's Reaction Series

Astronomy
- Tracking reflecting telescopes
- Spectrometer
- Radiotelescopes
- Formation of stars and planets (evolution theory)
- Planetary interiors (laws and theories)

Oceanography
- Ocean basin development

Meteorology
- Atmospheric phenomena
- Carbon dioxide and greenhouse gases
- Ozone creation and depletion
- Climate change

Twelfth Grade Physics
- Devices utilizing nuclear fission and fusion
- Metals and solid state materials
- Applications of electromagnetism
- Heat engines and refrigerators

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Texas SS&C

Environment
and
Fueling Around

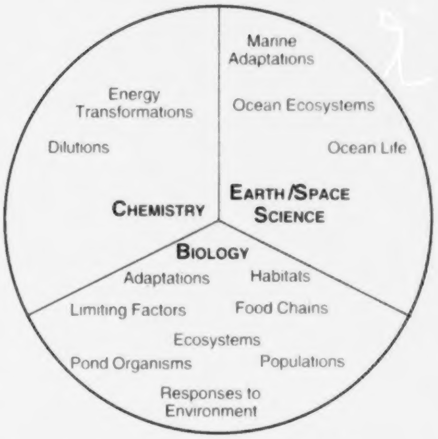
TEXAS SS&C
THE INTENDED USE OF THESE MATERIALS

These block materials demonstrate the basic tenets of the Scope, Sequence, and Coordination (SS&C) Project. They are intended to be used by science teachers at the appropriate grade level. Intentionally, no student materials have been included. The necessary instructions and background information have been written for teachers, and are inappropriate for use by students.

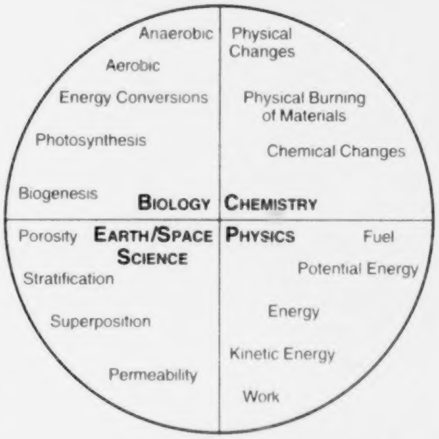
Role of the Blocks

The material developed for the blocks does not just represent the ideas and expertise of the Texas SS&C site, but reflects thirty years of learning research, school reform, and material development. The National Science Teachers Association (NSTA) SS&C Coordinating Center identified the concepts, ideas, rationale, and core content of each block. With the help of national discipline teams formed in biology, chemistry, earth/space science, and physics, the NSTA also identified activities appropriate for different grade levels. Building upon the NSTA's work, Houston SS&C staff, scientists, science teachers, and school educators decided which concepts and topics they wanted to stress in each block. The diagrams below illustrate the national concepts and related scientific disciplines included in Block I, Environment, and Block V, Fueling Around.

Block I—Environment


Marine Adaptations
Ocean Ecosystems
Ocean Life
EARTH/SPACE SCIENCE
Energy Transformations
Dilutions
CHEMISTRY
BIOLOGY
Adaptations
Habitats
Limiting Factors
Food Chains
Ecosystems
Pond Organisms
Populations
Responses to Environment

Block V—Fueling Around


Anaerobic
Aerobic
Energy Conversions
Photosynthesis
Biogenesis
BIOLOGY
Physical Changes
Physical Burning of Materials
Chemical Changes
CHEMISTRY
Porosity
EARTH/SPACE SCIENCE
Stratification
Superposition
Permeability
PHYSICS
Fuel
Potential Energy
Energy
Kinetic Energy
Work

The materials presented here have been reviewed and field tested on both a local and national level. As conceptual sequences were built and appropriate experiments chosen, those developing the material ensured that it provided adequate spacing, limited coverage, and reinforcement of concepts. The blocks clearly illustrate the spiral curriculum. Concepts presented early in the block are reinforced by later experiments, and these concepts inform activities that students will perform during future years. Consequently, the sequence of experiments is very important to achieving the block objectives and preparing students to meet National Science Education Standards. Activities are not randomly collected, but developed intentionally to build concepts and help the students make connections between material. Despite this organization, the material does not lend itself to "cookbook" experimentation. Teachers will need to make many instructional decisions in order to use the material successfully, including deciding how to introduce the material, assess student progress, provide adequate background information, and motivate student interest in the activities.

Role of the Teacher and the Student

This material assumes that teachers are already practicing good science teaching behaviors. Successful implementation of this material requires teachers to become active facilitators who guide student investigations by asking leading questions and encouraging students to develop and explore independent hypotheses. Pedagogical suggestions have been made, but they are not intended to be comprehensive.

This material also requires students to become active learners. During the field tests, students working with these materials began to take responsibility for their own learning and were not satisfied with unsupported assertions. They quickly began to seek evidence in order to explain why things worked the way they did.

These materials are not a panacea. They will not make science classrooms less crowded or provide better learning facilities. They will, however, begin the restructuring process proposed by the SS&C reform, reform that is greatly needed in secondary school science education. Field testing has shown that these materials can be used successfully by most teachers to provide students with the chance to acquire an understand and appreciation of science.

I have found power in the mysteries of thought.
Euripides, 438 B.C.

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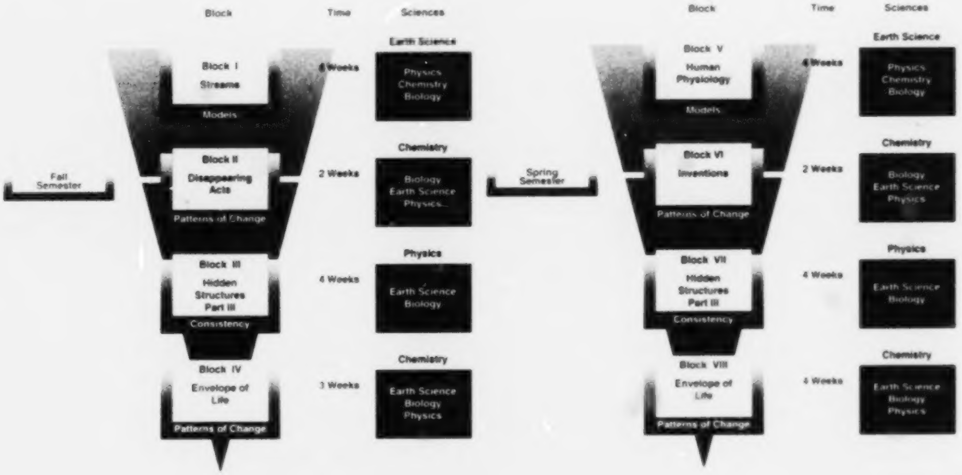
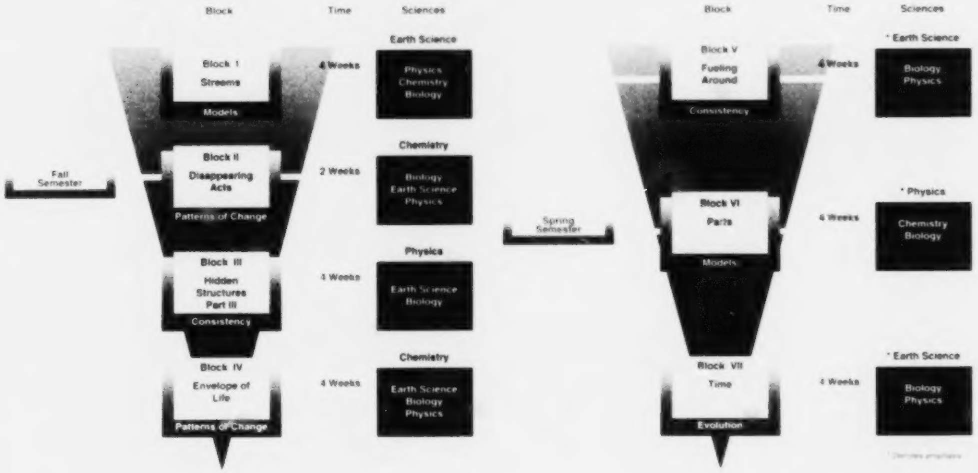
TEXAS SS&C
OVERVIEW OF FALL AND SPRING SEMESTERS

TEXAS SS&C PROJECT
SEVENTH GRADE - OVERVIEW OF FALL AND SPRING SEMESTER
BLOCKS I -VIII


Block
Time
Sciences
Fall Semester
Block I
Streams
Models
4 Weeks
Earth Science
Physics
Chemistry
Biology
Block II
Disappearing Acts
Patterns of Change
2 Weeks
Chemistry
Biology
Earth Science
Physics
Block III
Hidden Structures Part III
Consistency
4 Weeks
Physics
Earth Science
Biology
Block IV
Envelope of Life
Patterns of Change
3 Weeks
Chemistry
Earth Science
Biology
Physics
Block
Time
Sciences
Spring Semester
Block V
Human Physiology
Models
4 Weeks
Earth Science
Physics
Chemistry
Biology
Block VI
Inventions
Patterns of Change
2 Weeks
Chemistry
Biology
Earth Science
Physics
Block VII
Hidden Structures Part III
Consistency
4 Weeks
Physics
Earth Science
Biology
Block VIII
Envelope of Life
Patterns of Change
4 Weeks
Chemistry
Earth Science
Biology
Physics

TEXAS SS&C PROJECT
EIGHTH GRADE - OVERVIEW OF FALL AND SPRING SEMESTER
BLOCKS I -VII


Block
Time
Sciences
Fall Semester
Block 1
Streams
Models
4 Weeks
Earth Science
Physics
Chemistry
Biology
Block II
Disappearing Acts
Patterns of Change
2 Weeks
Chemistry
Biology
Earth Science
Physics
Block III
Hidden Structures Part III
Consistency
4 Weeks
Physics
Earth Science
Biology
Block IV
Envelope of Life
Patterns of Change
4 Weeks
Chemistry
Earth Science
Biology
Physics
Block
Time
Sciences
Spring Semester
Block V
Fueling Around
Consistency
4 Weeks
* Earth Science
Biology
Physics
Block VI
Parts
Models
4 Weeks
* Physics
Chemistry
Biology
Block VII
Time
Evolution
4 Weeks
* Earth Science
Biology
Physics
* Denotes emphasis

TEXAS SS&C
BLOCK I—ENVIRONMENT

The underlying theme of Block I is to allow seventh grade students to study the patterns of change that living organisms undergo. Students begin by studying how different organisms have adapted to their environments. They then gain a macrocosmic view of the environment by looking at some of the factors that can cause certain adaptations, such as the way different amounts of water, varying light levels, energy transformations, or temperature fluctuations can affect organisms. Since Block I is the first block in this series, it provides a foundation for the blocks that follow and for continuing study in ensuing grades.

The overall goal of Block I is to allow students to experience ecological concepts in a variety of settings. As a result of these experiences, students will:

- understand that the environment is a closed system, one that uses and reuses its resources and raw materials.
- become aware of the local environment and the consequences of upsetting its biotic and abiotic components.
- realize that each organism has developed specific characteristics to help it survive in its particular environment.

Using Block I with the *Middle Level Energy Series*

Two activities from Block I have been excerpted for use within the *Middle Level Energy Series*. These activities provide important foundational material that will help students better understand some of the environmental consequences of human energy needs. The first activity, **Nor Any Drop to Drink**, allows students to investigate how the unique chemistry of water makes it a "universal solvent." They will see that what appears to be "normal" water can contain beneficial and harmful components, a concept that will help them grasp the potential environmental risks involved with oil exploration and drilling, which they will encounter during the eighth and ninth grade. During the second activity, **Rot Around the Clock**, students observe the effectiveness of landfills, focusing on the environmental checks and balances that were considered before developing this technology. After completing these activities, students will be prepared to engage the concepts and assess the environmental risks associated with the later components of the *Middle Level Energy Series*.

Obviously, these activities work best when approached within the context of the rest of Block I and the other seventh grade block materials. We encourage instructors interested in pursuing an energy-oriented curriculum to consult the rest of the seventh grade block materials to develop an expanded and more comprehensive course of study.

TEXAS SS&C
BLOCK V—FUELING AROUND

The overall goal of Block V is to allow students to study energy, work, and fuels in several different contexts. By eighth grade, most students have heard that plants need sunlight, soil, and water to grow. Most also realize that plants make their own food, which in turn makes them a valuable source of energy for other animals. In this block, students will study the raw materials used to aid plants in photosynthesis, and the resulting products produced by plants. By the end of the first portion of the block, the students will have developed an equation for photosynthesis.

Because plants form an important energy source, the block continues by educating students about the scientific definitions of work and energy. The exercises provide students with a foundation in physics, and focuses on dispelling popular misconceptions surrounding this scientific terminology.

Finally, the unit describes how the energy conversions that occur in plants and other organic materials lead to the formation of oil and natural gas deposits beneath the surface of the earth. The geological series that concludes this block combines physics, earth science, and biology to help students understand the concepts of porosity and permeability as they relate to oil deposition and migration.

As a result of these experiences, students will:

- learn to distinguish the scientific definitions of work, energy, and fuel from the popular definitions.
- discover the natural processes that produce fuels such as oil and gas.
- explore the methods used to locate oil and examine how oil migrates.

Using Block V with the *Middle Level Energy Series*

In its entirety, *Fueling Around* provides important grounding in physical and geological concepts, which will be expanded upon during the ninth grade portion of this series. Students should also begin to see how the environment is interconnected: what happens in a plant's ecosystem can determine the future availability of petrochemicals, for example. *Fueling Around* demonstrates the flow of energy through nature, in preparation for the ninth grade block, which will ask students to assess the impact that oil exploration and consumption has on the environment.

Proposed Daily Schedule

The following schedule of activities merely suggests a possible way to organize the activities and does not coincide with a literal day-by-day schedule. If students show an interest in a particular topic, activity, or subject, feel free to extend the activities to meet their needs. Teachers should, however, pay careful attention to the sequence of activities. The sequence provided here not only allows for important concept building, but also helps students realize certain objectivies. Bolded activities indicate long-term projects that students will observe over several class periods.

Day	Title of Activity
1-5	**Light and Dark**
6	Where Does Carbon Come From?
7	**Pond Bottom**
8	Day of Reflection
9	What Happens to the Energy of a Pendulum?
10	Who Did More Work?
11	Down the Hill
12	Lifting Heavy Objects
13	Day of Reflection
14	Hol(e)y Rocks
15-16	I've Got Connections
17-18	How Did It Get There from Here?
19-20	Where, Oh Where Can It Be?

Nor Any Drop to Drink

Students investigate water as an essential substance for life and as the ultimate solvent for biological and industrial processes.

Time Needed: Three or four hours

Objectives: After completing this activity, students will be able to predict the consequences of changing environmental factors on an ecosystem and describe environmental risk factors.

Processes: Observing, inferring, measuring, communicating, classifying

Materials: (for each group)
Hardware for all Parts:

- **5 test tubes with corks or stoppers**
- **test tube rack**
- **beaker or soup can**
- **masking tape**
- **marker**
- **balance**
- **10 mL graduated cylinder**
- **glass stirring rod**
- **1 well plate or reaction strip**
- **20 toothpicks**
- **2 pipettes or medicine droppers**
- **paper towels**
- **sink or wash water basin**

Part A: Tasting the Waters

- **50 mL numbered samples of tap, distilled, mineral (no bubbles), and bottled spring waters in containers suitable for consumption**

Part B: Testing the Waters

- **10 mL iron-supplemented distilled water**
- **10 mL 5% calcium chloride solution**
- **5 g table salt**
- **10 mL 5% hypochlorite solution or liquid bleach**
- **10 mL liquid detergent**
- **200 mL distilled water**
- **100 mL iron indicator solution**
- **50 mL hardness indicator solution**
- **10 mL chlorine tester**

Part C: Watering Algae

- **4 petri dishes**
- **algae culture**
- **200 mL distilled water**
- **20 mL 5% potassium phosphate solution**
- **20 mL 5% hypochlorite solution or liquid bleach**
- **20 mL 5% phosphate laundry detergent solution**
- **graph paper**

Part D: Treat Me Right

- **200 mL water test sample**
- **50 mL iron indicator solution**
- **50 mL hardness indicator solution**
- **10 mL liquid detergent**

10 mL chlorine tester
beaker
200 mL distilled water
10 mg bentonite or other available coagulant
filter paper
funnel
hand lens and/or microscope

TEACHER PRELAB PREPARATIONS: FOR PART A: TASTING THE WATERS

1. Keep in mind that the samples of tap water, distilled water, mineral water, and bottled spring or drinking water are to be tasted by the students and prepare them accordingly. One way to let the students taste each sample safely is to provide them with pieces of plastic soda straw for each sample. The students dip one end of the straw segment into the sample, use a fingertip to close the other end of the straw, and release the water into their mouths by moving their fingertip. Other methods may be more suitable for your circumstances.
2. You should be the only one who knows the identity of each sample, so take appropriate measures to conceal the water identities from the students until the end of Part B. Mineral water has a very distinctive taste and is also effervescent; the bubbles will clearly distinguish it from the other water samples. You can disguise the mineral water by periodically shaking or stirring it and allowing it to sit in an open container until it goes "flat." Be aware that the temperatures of the samples will influence the intensity of their tastes.

FOR PART B: TESTING THE WATERS

1. Consider preparing all of these solutions in front of the students before they perform the tests. This will help the students to see that water can contain many substances while still looking like water. Students can also prepare their own solutions if the materials are available.
2. To prepare **iron-supplemented distilled water**, dissolve one dietary iron supplement tablet in 1 liter of distilled water. Purchase iron supplement tablets from grocery or drug stores. The least expensive brand is adequate for this activity. Since iron supplement tablets are coated to protect the stomach, rinse off the coating before dissolving the tablet in distilled water. One liter of iron-supplemented distilled water will be enough for this experiment.
3. To prepare a **5% calcium chloride solution**, dissolve 25 g of calcium chloride dihydrate in 500 mL of distilled water.
4. You can purchase hypochlorite solution in a 5% concentration at a grocery store or drug store (liquid laundry bleach is usually a 5.25% hypochlorite solution). Remind students to work carefully with hypochlorite solutions since they can irritate the skin and eyes, and can damage clothing.
4. Well plates, used in microchemistry, are ideal for this activity. Well plates significantly reduce the quantities of

chemicals needed, are inexpensive, and can be easily cleaned. Well plates can be obtained from scientific supply companies. Students will need up to six wells during this activity. Well plates are available with up to 96 wells per plate and have different capacities. Reaction strips (which usually contain contain eight to twelve wells) are less expensive, but are much more easily spilled, lost, or broken. Trays or frames to protect the strips are also commercially available. If reaction plates or strips cannot be found, substitute other appropriate containers, such as artist's paint wells, which are usually available in art supply stores. Remember to adjust the amounts of solution appropriately.

Reaction or Well Plate

Reaction Strip

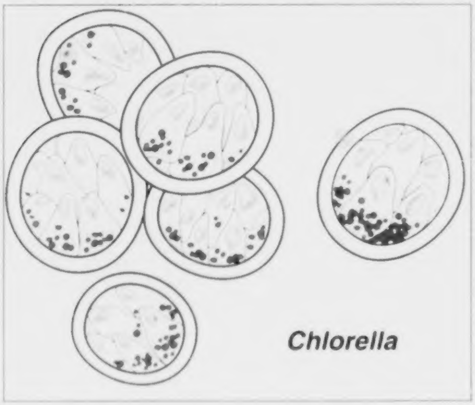
5. To prepare an **iron indicator solution**, dissolve four iron LR Code 3725 tablets (available from the LaMotte Company, PO Box 329, Chestertown, Maryland 21620, 800-344-3100) in 100 mL of distilled water. These tablets contain a reducing agent that breaks down weakly complexed forms of iron and converts iron from the ferric to the ferrous form. This indicator is quantitative in that greater iron content is indicated by a darker solution color. Feel free to substitute other iron indicators.
6. To prepare a **water hardness indicator solution**, dissolve four Hardness T Code 6917 tablets available from the LaMotte Company) in 100 mL of distilled water. These tablets contain two compounds that react at different hardness concentrations. In low concentrations, the solution turns blue. In high concentrations, the solution turns red or pink. Other indicators may be substituted.
7. The liquid dish washing detergent that you chose for the sudsing test should not contain additives designed to overcome the effects of calcium and magnesium in hard water. A number of inexpensive soaps, such as Ivory and Palmolive, work best. Be sure to test your soap beforehand.
8. Many chlorine indicators are available for testing aquariums and swimming pools. The LaMotte Company also makes DPD #4R tablets for indicating the presence of chlorine. Chlorine indicators typically turn samples red or pink if chlorine is present.
9. Because the students will need to clean and dry pieces of equipment repeatedly, provide plenty of towels and water. Keep some extra distilled water on hand for use throughout these activities.

FOR PART C: WATERING ALGAE

1. Have your students make their own

phosphate solutions (5% = 5 g dissolved in 100 mL distilled water, 1% = 1 g dissolved in 100 mL distilled water) or make a large quantity of stock solution (5% = 25 g potassium phosphate dissolved in 500 mL of distilled water).

2. Green algae, particularly *Chlorella*, is the best candidate for this experiment. Look for *Chlorella* in pond water or purchase it as a pure sample from a scientific supply store.



Be sure to purchase or otherwise supply the proper media to culture and maintain the algae. Knop's solution is an effective culture that you can prepare easily by dissolving the following solutes in one liter of distilled water in the order specified: 1 g potassium nitrate (KNO_3); 1 g magnesium sulfate ($MgSO_4$); 1 g potassium hypophosphate (K_2HPO_4); and 3 g calcium nitrate $Ca(NO_3)_2$. The solution will form a precipitate if left standing, so shake it each time you use it. Be sure to use distilled water, as chlorine or copper additives will kill most algae. When you have prepared the media, add some to a flask along with a small amount of fresh algae. Place the flasks under cool-white fluorescent tubes for seven to ten days to allow the cultures to grow. Then move the cultures to an area of lower illumination until you are ready to begin the experiment. Most green algae survives best at a temperature range of 15 to 26 degrees Celsius.

3. The inoculated petri dishes will need to be kept in a sunny place for several days. Select a space where the specimens will be undisturbed and the students will still have access to them.

FOR PART D: TREAT ME RIGHT

Provide mystery samples for the students to test and treat. Make your own mystery samples, or ask the students to bring them in. Good samples can be found in mud puddles, ponds, birdbaths, decorative fountains, streams, bayous, etc. Because samples such as these can contain virulent organisms, take care in selecting and handling them.

ACTIVITIES:

PART A: TASTING THE WATERS

I. EXPLORING IN SMALL GROUPS

Explain to the students that the four samples are all water. Ask them to taste each sample and compare other easily observed properties.

II. DEVELOPING IN A LARGE GROUP

During a large group discussion, help students conclude that there must be different things dissolved in each sample. In the following activities, they will be working with percentage solutions, so you may need to refresh the concepts of percentages and concentration. A five percent *X* solution means that there are five *X*s in every 100 parts sampled. Here are some questions:

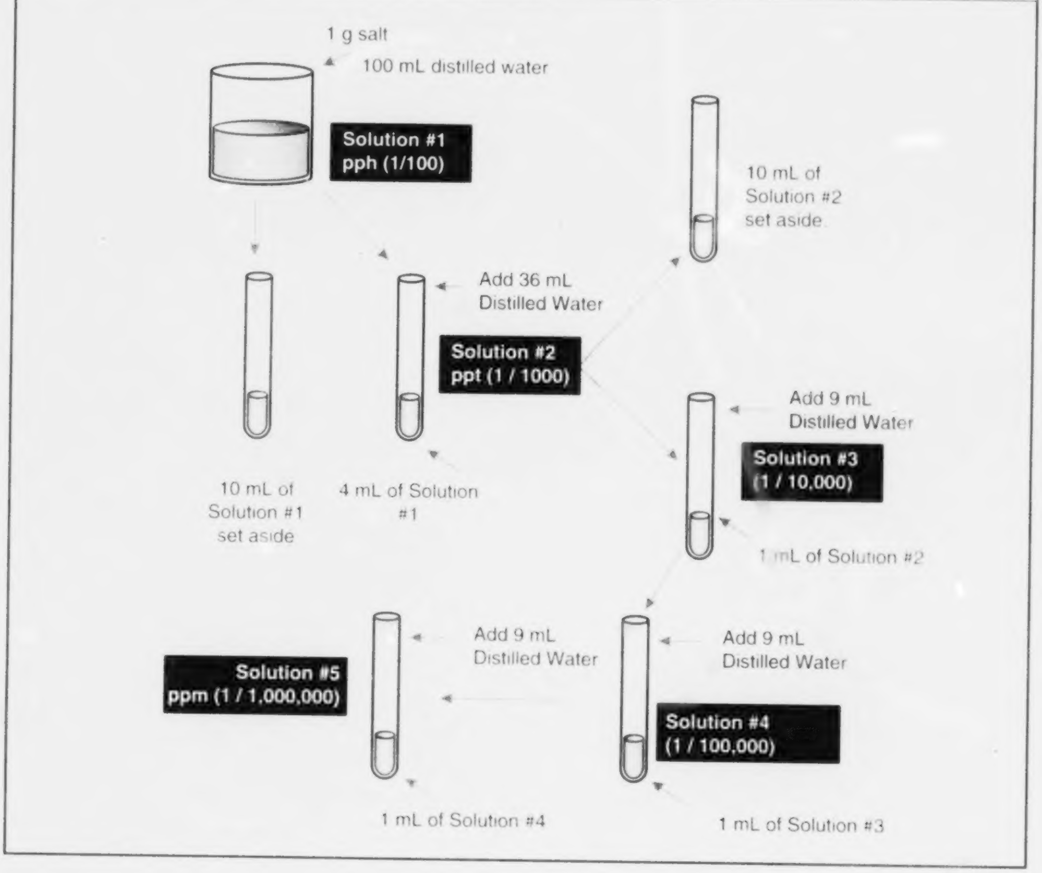
1. How are the samples alike? How do they differ?
2. What could cause any differences in the taste of the samples?
3. What does five percent or 25 percent mean?

PART B: TESTING THE WATERS
I. EXPLORING IN SMALL GROUPS

In the following sections, students will perform a variety of different water treatment tests. Testing kits are available from Hach and LaMotte (see references). These tests require indicators provided by LaMotte. Several of the tests require the students to create a dilution series. The series for the sudsing test is illustrated below.

Each separate test will provide students with a positive test reaction at different concentrations. After observing

Dilution Series


1 g salt
100 mL distilled water
Solution #1
pph (1/100)
10 mL of
Solution #2
set aside
Add 36 mL
Distilled Water
Solution #2
ppt (1 / 1000)
Add 9 mL
Distilled Water
Solution #3
(1 / 10,000)
10 mL of
Solution #1
set aside
4 mL of Solution
#1
1 mL of Solution #2
Add 9 mL
Distilled Water
Add 9 mL
Distilled Water
Solution #5
ppm (1 / 1,000,000)
Solution #4
(1 / 100,000)
1 mL of Solution #4
1 mL of Solution #3

the positive test, students should repeat the test on the mystery samples from Part A.

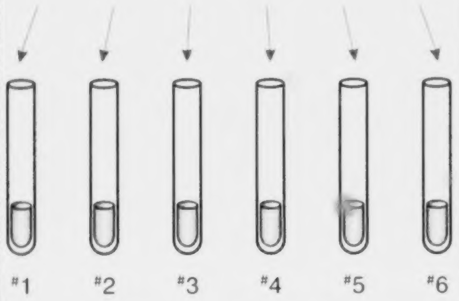
Sudsing Test

This test will indicate the presence of salt in solution. Instruct your students to do the following:

- Use a glass stirring rod to mix each new solution. Thoroughly rinse and dry the stirring rod and graduated cylinder between each solution. Use the tape and marker to label each solution as you make it.
- Measure 1 g of table salt and dissolve it in 100 mL of distilled water. Pour 10 mL of this solution (#1) into a test tube and set it aside. The concentration of solution #1 is pph (parts per hundred), which means that this solution contains one part of salt per 100 parts of water.
- Measure 4 mL of solution #1 into another test tube and add 36 mL of distilled water to it. Pour 10 mL of this new solution (#2) into another test tube and set it aside. The concentration of solution #2 is ppt (parts per thousand), which means that this solution contains one part of salt per 1,000 parts of water.
- Pour 1 mL of the remaining solution #2 into another test tube and add 9 mL of distilled water to make solution #3. Set this aside. Repeat this procedure to make solutions #4 and #5. These solutions will have concentrations of parts per ten thousand, hundred thousand, and million respectively.
- Add two drops of dish washing detergent to each solution. Cork the test tubes and shake them vigorously 20 times. Place them in the test tube rack. Examine the results and record your observations. Save this series to compare with your mystery samples.

To perform the sudsing test. . .

Add 2 drops of dish washing detergent to each solution.



Cork / Stopper / Shake 20 times.

- To perform the sudsing test on your mystery samples, add two drops of dish washing detergent to 10 mL of mystery solution. Cork the test tubes and shake them vigorously 20 times. Examine the results and record your observations.

Hardness and Softness Test

This test indicates the presence of calcium and magnesium in water. Have your students do the following:

- Measure 10 mL of the hardness indicator solution into each of three test tubes and set them in the rack.
- Use the 5% calcium chloride solution and distilled water to make a 1% calcium chloride solution (do this by adding 40 mL of water to 10 mL of the 5% solution).
- Add three drops of distilled water to

the first indicator solution. Add three drops of 5% calcium chloride solution to the second indicator solution. Add three drops of 1% calcium chloride solution to the third indicator solution. Observe the results and record your observations. Save this series to compare with your mystery samples.

- To test the hardness of the mystery water samples, add three drops of mystery sample to 10 mL of the hardness indicator solution.

Iron Test

This test indicates the presence of iron in water. Have your students use the iron indicator solution, iron supplemented water, and distilled water to perform the same procedure used for the hardness and softness test. Repeat the procedure for each mystery sample.

Chlorine Test

This test indicates the presence of chlorine in water. *Note: Remind the students to be careful when using hypochlorite, as it can irritate the skin and eyes and will bleach color out of clothing. Explain to them that, in this activity, they will be using drops of substances and wells instead of mL and test tubes, but the procedures and relationships are still the same.* Make sure their samples are fresh as chlorine evaporates over time. Have your students to the following:

- Measure ten drops of the 5% hypochlorite solution into the first well.
- Put four drops of distilled water into the second well and add one drop of the solution from well 1 to produce a 1% solution in well 2.
- Add one drop from well 2 to nine drops of distilled water in well 3 to make a 0.1% solution. Continue this procedure until you have made a 1 ppm solution.
- Add one drop of the chlorine tester to each of the wells and record what happens. Keep this dilution series to compare with your mystery samples.
- To test for chlorine in the mystery samples, add 10 drops of the sample to a well and mix in one drop of the chlorine indicator solution. Record what happens.

II. DEVELOPING IN A LARGE GROUP

Ask each group to report how they identified the mystery samples, explain the procedures they used, and support their results. Then reveal the actual identities of the water samples. Be sure to clarify that some of the tests are quantitative and others are qualitative. Discuss what these terms mean. Following are some questions to help you guide discussion.

Sudsing Test

1. What is the concentration of salt in each of the solutions you have made?
2. What were the results of the sudsing tests you performed?
3. How does the amount of a mineral dissolved in water affect the solution's ability to form soap suds?

Hardness and Softness Test

1. What colors indicate hard or soft water?

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A Joint Project with the American Petroleum Institute

2. Can you tell how hard or soft the water you test is?
3. What liquid do you think was used to make the indicator solution and why do you think that liquid was chosen?
4. What is meant by hard and soft water?
5. What are some of the effects of using hard water as opposed to soft water in daily living? Should you water house plants with hard or soft water?

Iron Test

1. What color indicates the presence of dissolved iron?
2. Can you tell how much iron is present in a sample?
3. What might be some effects of having iron in your water?

Chlorine Test

1. What color indicates the presence of dissolved chlorine?
2. Can you tell how much chlorine is dissolved in the water?

Mystery Samples and Development Questions

1. Describe your findings for each mystery sample.
2. What other things might you find in a water sample that we have not investigated so far?
3. Why was distilled water used to change the concentrations of the solutions?
4. What does 0.5 percent or 0.001 percent mean?
5. What does 1 ppm mean?
6. What is pure water?
7. What are the advantages and disadvantages of qualitative and quantitative indicators?

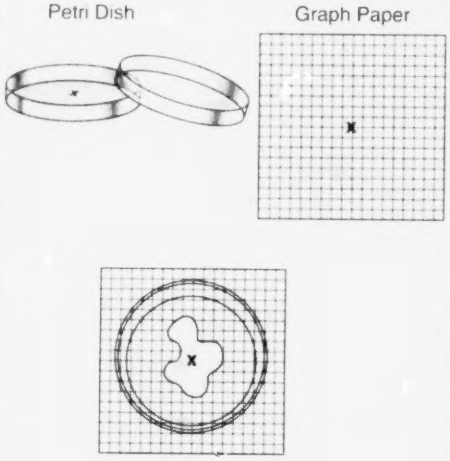
PART C: WATERING ALGAE

I. EXPLORING IN SMALL GROUPS

You can assign concentration levels of potassium phosphate, laundry detergent, or chlorine solutions to each group for testing, or let the groups select their own concentrations, making sure they investigate an effective range (for example, students can dilute the 5% solutions to 4%, 3%, 2%, or 1%. The students should be able to generate fairly accurately their own solution concentrations. Have the students record how they developed the concentrations. A fourth dish, containing distilled water, will serve as the control.

Students will measure the growth of the algae by using the graph paper to create a grid under the petri dishes. Have your students do the following:

- Turn the bottom petri dish over and mark a small X in the center of the dish. Then, mark an X near the center of a sheet of graph paper where two major lines intersect.
- Using a toothpick, inoculate an area about 1 cm in diameter on the inside of the bottom dishes just over the Xs with algae culture.
- Use a clean dropper to add test solutions to cover each culture and fill each bottom dish about half full.
- Carefully place each dish on the graph paper, matching up the Xs, and record the number of graph squares covered by the algae culture. These squares will provide areas of reference in future writing and drawings.



Petri Dish with Algae on graph paper.

- Cover and label the dishes and put them in the sunny place selected. You should observe the cultures each day and count the number of squares covered by the algae in each dish.

II. DEVELOPING IN A LARGE GROUP

Encourage the groups to share their results periodically during the course of this experiment. At the conclusion of the investigation, help them to compile the data obtained and form some conclusions. Here are some questions to help you guide the students:

1. What effect does potassium phosphate, detergent with phosphate, or chlorine have on the growth of algae in water?
2. How does the concentration of potassium phosphate, detergent with phosphate, or chlorine affect the growth of algae in water?
3. How might the natural environment be affected by stimulating or reducing the growth of algae in water?
4. Why is chlorine added to swimming pools?
5. According to your findings, how much of each substance tested can be present in the water before algae growth is affected?
6. According to your findings, what is the maximum amount of each substance tested which should be allowed in environmental waters?

PART D: TREAT ME RIGHT

I. EXPLORING IN SMALL GROUPS

Give each group 200 mL of a water test sample. Their task will be to find out what is in the sample and to treat it by using filters, coagulant, and chemicals to make it as pure as they can. Because they will be treating their samples with a coagulant, it may take quite a while for the coagulant to precipitate out of the solution. They can use this time to work on the other tests or on selected media materials concerning water, water treatment, or water quality. Have your students do the following:

- Use the hand lens to examine the sample carefully. Try to determine what kind of visible debris is present and if any organisms exist in the sample. Agitate the sample with a stirring rod and let it stand until any larger particulate matter has settled to the bottom.
- Put filter paper into the funnel and carefully pour about 100 mL of the sample through the funnel-filter into another beaker, disturbing the sediment as little as possible. Use the

hand lens to examine the filtrate, again taking note of any remaining particulate matter or organisms.

- Add a pinch (about 10 mg) of coagulant to the filtered sample, agitate it, and let it stand until any large particulate matter has settled to the bottom. Filter the water as before and use the hand lens to check for clarity. Remember to wash your hands with soap and water after handling the untreated sample.
- Use the tests from Part B to determine the quality of the treated sample, with distilled water as a control. Record your procedures and observations.

II. DEVELOPING IN A LARGE GROUP

Encourage the students to share their findings and observations. Use these questions to guide the discussion:

1. What did you find in the original untreated sample?
2. How effective is allowing the sample to settle out as a water treatment procedure?
3. How effective is filtering as a water treatment procedure?
4. How did your treatment procedures change the contents of your water sample?
5. What is the purpose of adding chlorine to the sample?
6. For what purposes do you think your treated sample could safely be used by human beings?
7. What other treatment procedures might be used to make the treatment sample more pure?

BACKGROUND INFORMATION:

The title of this activity was pulled from Samuel Taylor Coleridge's poem, "The Rime of the Ancient Mariner." Coleridge provides his readers with an apparent oxymoron in the lines, "Water, water, everywhere. . . Nor any drop to drink," but these words actually provide an elegant description of the reality of water availability on our planet. While most of the Earth's surface is covered with water, 97 percent of it is contained in the oceans. Salt water is not suitable for most human needs. In addition, most of the remaining water is frozen in ice caps. In the end, only a tiny fraction of the water on this planet is available to humans. And yet, in the United States alone, each person uses about 400 liters per day, and industrial and agricultural needs consume 385 billion liters per day.

Why do we use so much water? Primarily because of its amazing capacity to serve as a solvent for biological and industrial processes. A solvent is something that dissolves another substance (known as a solute). Water can dissolve a wide array of compounds because of its chemical structure. You may already know that water is a molecule composed of two atoms of hydrogen and one atom of oxygen. The molecule formed by these atoms is polarized—the oxygen side is negatively charged and the hydrogen side is positively charged. In solution with other compounds, the charged ends of the water molecule attract other charged particles. Because water is an extremely stable compound, its attractive forces typically pull apart other molecules, dissolving them.

In this activity, students will get to see a wide variety of substances dissolved in water, including iron, chlorine, calcium, and salt. Some of these compounds naturally occur in water. Iron, for example, usually exists in small quantities; its presence frequently produces orange stains on our sinks and bathtubs. Calcium and magnesium also appear naturally in water—the quantity of these two minerals dictates whether your water is hard or soft. But humans also add substances to water. Chlorine, for instance, is added to kill bacteria living in the water and to control algae. Carbon dioxide is frequently added to water to produce "bubbly" beverages, such as soft drinks and sparkling water. Unless water is profoundly contaminated, it is impossible to tell just by looking at it that anything is dissolved in it. Taste can tell you a little bit, but typically the only way to know for sure what is in water is to run indicator tests, as the students will do during this activity.

The trouble with water's ability to serve as a solvent is that it can contain harmful substances. You may have heard of people getting lead poisoning from their drinking water. In the past, water pipes were made from lead, and as the water rushed through the pipes, the lead leaked into the water supply. In addition, gallons of sewage and other wastewater literally pour out of our homes, schools, and factories every day. Water treatment facilities monitor our entire water supply. These facilities clean waste water, regulate the amount of chlorine and minerals in drinking water, and develop water appropriate for specific industrial applications. As you can imagine, these treatments are quite expensive. But if we insist on taking water for granted, we will continue to become even more dependent upon these facilities to produce the water we need.

PRACTICAL APPLICATIONS:

For application purposes, students should begin to understand that the liquid they know as water actually contains trace amounts of other substances. The measure of "parts per million" expresses how these other substances contribute to water pollution or contamination. Students should also realize the consequences and effects that extraneous materials can have on household water, as well as the nature and complexity of water treatment and supply in their communities.

NOTES:

Teachers should use these activities to introduce phenomena (density, concentration, salinity, solute, etc.) only as they relate to water purity. Be sure to emphasize that students should handle all untreated water samples and hypochlorite carefully, and that they should observe all safety precautions. Remind students to remove any tape labeling as they clean up their equipment.

ADAPTED FROM:

Coble, C. R., Murray, E. G., Rice, D. R. (1987). *Earth Science*. Englewood Cliffs, NJ: Prentice Hall, pp. 238-61.

Hach Company. (1984). *Chemical Procedures Explained*. Loveland, CO: Hach Company.

James, Daniel E. (1978). *Culturing*

Algae. Burlington, NC: Carolina Biological Supply Company.

LaMotte Company. (1989). *The Tapwater Tour*. Chestertown, MD: LaMotte Company.

Maton, A., et. al. (1993). *Ecology: Earth's Natural Resources*. Englewood Cliffs, NJ: Prentice Hall, pp. 50-54.

Mitchell, Sharon G. (1991). *Laboratory Solutions for the Science Classroom*. Batavia, IL: Flim Scientific, Inc.

Morholt, Evelyn and Brandewein, Paul F. (1986). *Sourcebook for the Biological Sciences*. San Diego: Harcourt, Brace & Janovich.

DEVELOPMENT QUESTIONS:

1. How can the purity of water be described?
2. What does 1 ppm mean?
3. How does ppm compare to one drop per gallon?
4. What are some processes used in the treatment of water?

APPLICATION QUESTIONS:

1. How could natural causes affect water purity?
2. How could industrial practices affect water purity?
3. What observable consequences might result from the presence of calcium, magnesium, iron, copper, chlorine, phosphates, organic matter, or organisms in household and commercial water supplies?

ASSESSMENT:

Have the students perform appropriate tests to determine the contents of an unknown water sample that you have prepared for them.

EXTENSIONS:

As part of a further study of water treatment, invite a public and/or commercial water treatment specialist to visit your classroom, or arrange a visit to a water treatment facility. You could also try distilling some water on a small scale to demonstrate another step in water treatment. For a large scale project, have students collect and test water samples from a variety of locations. Arrange for them to have Water Pals (similar to pen pals) in other areas to obtain a greater variety of samples for testing.

Rot Around the Clock

Students investigate decomposition by creating their own miniature landfills.

TIME NEEDED: Three or four hours

OBJECTIVES: After completing this activity, students will have learned to predict the consequences of changing environmental factors on an ecosystem and describe environmental risk factors.

PROCESSES: Observing, inferring, measuring, communicating, and classifying.

MATERIALS: (for each group)

PART A: Introduction

- **1 small piece banana peel**
- **1 small plastic recloseable sandwich bag**
- **water, soil, scissors, and other materials to serve as variables**

PART B: Landfill Bottles

- **1 two-liter bottle or plastic container**
- **2 cups of soil**
- **funnel**
- **assorted trash (paper, plastic, metal, wood, etc.)**
- **soil thermometer or lab thermometer**

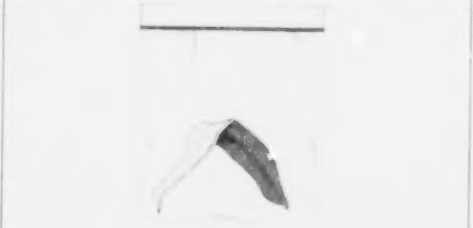
TEACHER PRELAB PREPARATIONS:

You may want to set up the pieces of banana peel ahead of time. For the assorted trash, students will need a variety of garbage including such items as plastic and paper. When they construct their landfill, have available a variety of items such as rubber tubing, different types of soil, sand, and pebbles. Allow them to be inventive and creative.

ACTIVITIES:

PART A: PEEL AWAY

Have students place pieces of banana peel into recloseable plastic bags. The students should expose their bags to varying conditions, holding certain variables constant. For example, place some bags in light, others in dark. Add soil or water to some bags. Allow air to enter certain bags by cutting small holes in the bags. After a few days, have the students examine the unopened bags and look for changes.

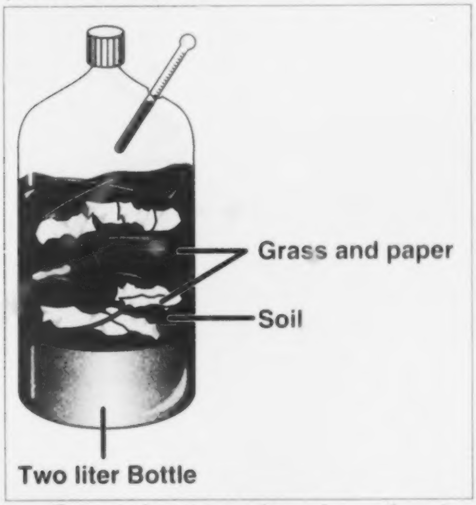


Banana Peel in Plastic Bag

PART B: LANDFILL BOTTLES

I. EXPLORING IN SMALL GROUPS

After the students examine the banana peels and draw some conclusions, give them materials for Part B. Challenge them to create a chamber in their two-liter bottle that will maximize rotting of all materials. Remind them of the variables that helped the banana peels decompose.



Over at least two days, have the students measure the temperature at the top and in the center of their landfill bottles. The temperature will increase initially due to the heat produced by decomposer activity. The temperature will decrease as the decomposers deplete the oxygen in the container and decrease their chemical activities.

II. DEVELOPING IN A LARGE GROUP

Students examine the bottles once a week for a month (remind the students not to open the bottles, as they will contain fumes). Discuss with students what was effective and what was not.

One way to provide context for the students is to relate the decay rate of certain materials to their own lifespan. Ask the students to write down the year that they were born, the year their mother or father was born, and the year that their grandmother or grandfather was born. (Notify them of these questions before this discussion so that they can obtain the answers at home). Then select some pieces of litter, such as paper, aluminum cans, steel cans, glass bottles, plastic bottles, and a piece of wool. Ask the students to predict how long each material will take to decompose.

After discussing the predictions, share the actual decomposition rates of these materials. A diagram has been provided so that you can make a transparency. Relate these rates to the human lifespan. Ask them what items would have decomposed if they had been thrown out when their grandparents were born.

Some additional questions may help you guide the discussion.

1. How were the different materials affected by your miniature landfill?
2. If you were to plan your chamber again, what would you change?
3. How would you build a chamber that would rot only paper? only plastic? only wood?
4. A new bacteria has been created that decomposes plastic, but it needs oxygen to work. How would this new bacteria affect landfills?

BACKGROUND INFORMATION:

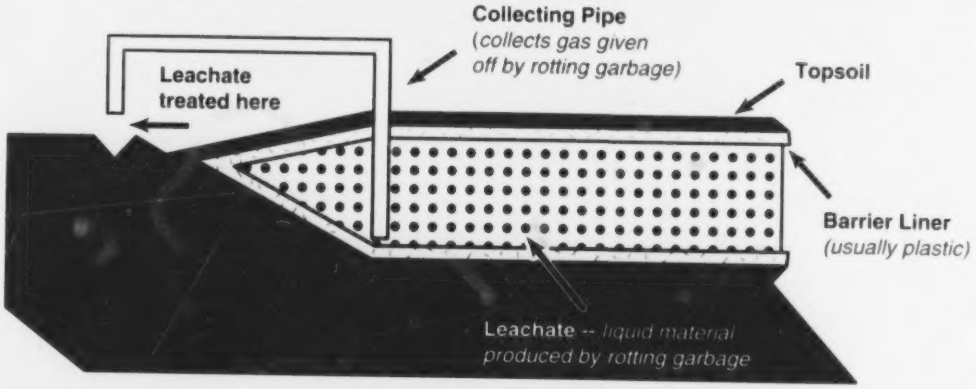
In nature, decomposition (or rotting) is a fundamental part of the food chain.

When animals and plants die, their remains are eaten by small microorganisms and bacteria. Some of these organisms decompose material quickly, and because they need oxygen to survive, they are known as aerobic microorganisms. Other microorganisms, which are anaerobic because they do not require oxygen, also decompose material, though they do so much slower than aerobic microorganisms. Through decomposition, energy from the upper parts of the food chain is converted back into material that can be used by lower members of the chain, continuing the flow of energy through nature.

Humans, however, have disrupted the natural process of decomposition. Our waste is not returned to the environment for other organisms to use, but instead goes into dumps or sewers. In this activity, students will investigate whether our methods of disposing of waste work as well as nature's methods.

In the first half of this century, most solid and municipal waste took the form of garbage, yard waste, and other nonhazardous material. Getting rid of it was simple—deposit it in a large open dump, where it would be periodically burned and covered with dirt. But dumps were messy, smelly, and unsightly, and as our society began to rely more and more on "throwaway" materials, civil engineers turned to sanitary landfills to deal with solid waste. Sanitary landfills compact garbage so that it takes up less space and, to reduce the debris and odor of the garbage, landfills are covered with a layer of soil and sealed daily. A secondary benefit of landfills is that once they have been filled to capacity, they can be landscaped to create parks, gardens, and recreation areas.

But as scientists have studied landfills, they have discovered some problems with them. We can blame some of the problems on the increased volume and changing composition of garbage in the latter half of this century. Americans now produce four billion tons of solid waste every year. And today's solid


Collecting Pipe
(collects gas given off by rotting garbage)
Leachate treated here
Topsoil
Barrier Liner
(usually plastic)
Leachate -- *liquid material produced by rotting garbage*

A landfill in cross-section.

waste contains many materials, such as plastics and toxic industrial wastes, that can contaminate soil and groundwater indefinitely. Surprisingly, though, the primary problem with landfills is that they prevent the decomposition of biodegradable material (material that microorganisms typically breakdown). This is because landfills pack garbage so tightly that the fast-eating aerobic microorganisms die from lack of oxygen. The surviving anaerobic bacteria simply cannot handle the amount of trash produced. Consequently, biodegradable garbage, including newspaper, can remain in landfills for decades. In fact, most landfills contain six times more paper than plastic. And even modern degradable plastics do not decompose in a landfill. Degradable plastic is broken down by light, which is scarce in most landfills.

In this activity, students will have the chance to see what conditions promote decomposition. Encourage them to consider whether the methods used in their miniature landfills could be applied on a larger scale in landfill situations. You can also use this activity as an opportunity to discuss the importance of reuse and recycling.

PRACTICAL APPLICATIONS:

The proper disposal of trash is an important concern to everyone. The design of landfills can accelerate decomposition or inhibit it.

NOTES:

School trash cans are always good sources of assorted trash.

ADAPTED FROM:

Ashford, Pan. (May, 1992). "My Grandchildren's Trash." *Science Scope*, pp. 21-23.

Burkett, K. (September, 1990). "Make it rot." *Super Science Blue Edition*, pp. 18-23.

Maton, A., et. al. (1993). *Ecology: Earth's Natural Resources*. Englewood Cliffs, NJ: Prentice Hall, pp. 72-73.

Moeller, D. W. (1992). *Environmental Health*. Cambridge, MA: Harvard Univ. Press, pp. 103-31.

Swarthout, Flora L. (September, 1993). "The Science of Composting." *The Science Teacher*, pp. 27-29.

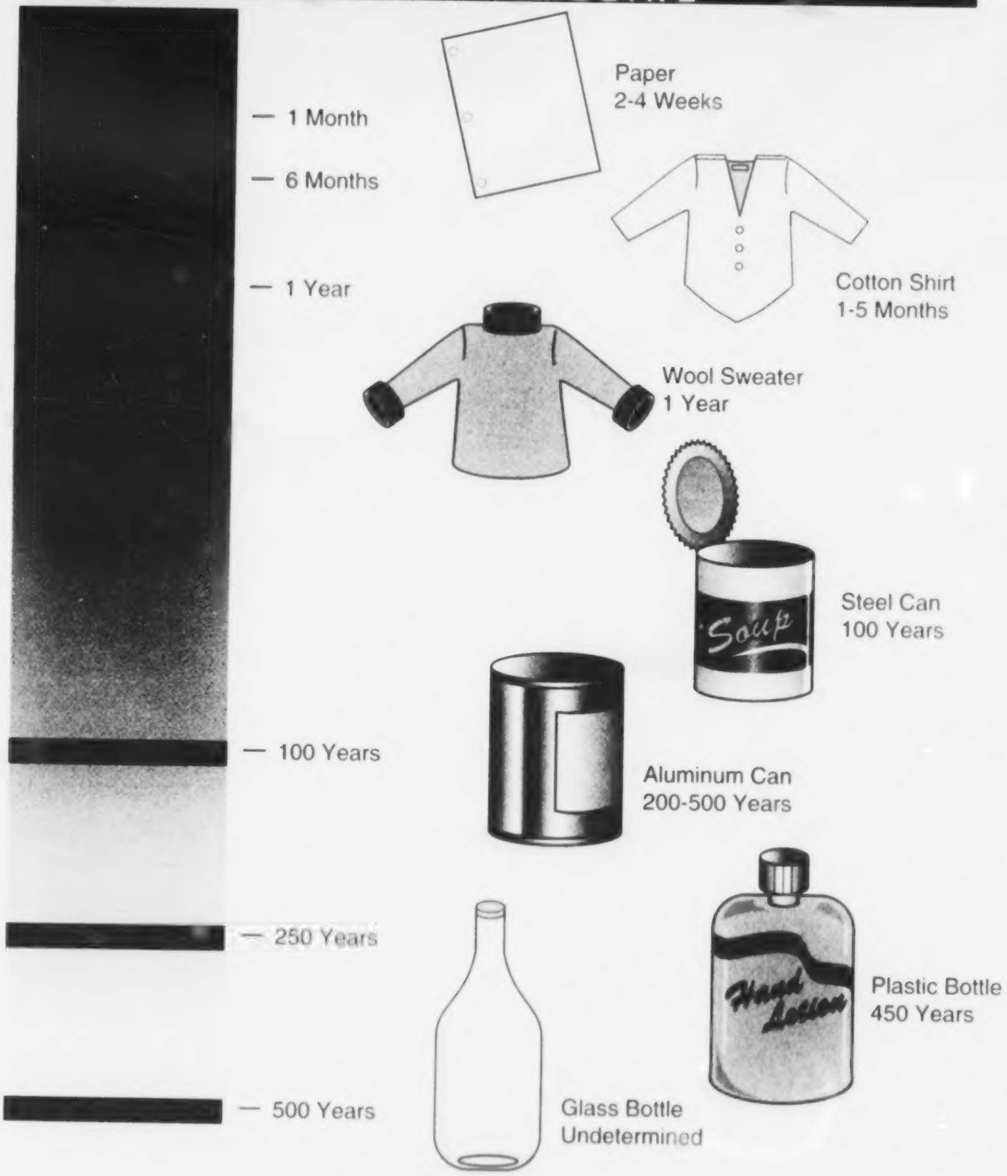
ASSESSMENT:

Give the students different materials and have them describe the best way to decompose them.

EXTENSIONS:

Students can look at the effects of recycling on landfill composition, and devise methods to decrease the amount of garbage in their communities. Have students examine the soil from their landfills using a microscope. Can they see the decomposers?

LITTER TIMELINE



Light and Dark

Students will investigate some of the factors that are necessary for photosynthesis to occur. In Part A, students will see how plants use the products of photosynthesis to produce starch. In Part B, they will learn that gas is another product of photosynthesis, and in a series of related activities, will investigate the nature of this gas production.

TIME NEEDED: Five hours

OBJECTIVES: At the end of this activity, students will be able to identify the basic requirements for photosynthesis and recognize its products.

PROCESSES: Observing, inferring, predicting

MATERIALS:

Part A: Leaf Portraits

(for each group)
- **specially-prepared leaves**
- **2 petri dishes**
- **dilute iodine solution in dropper bottle**
- **tweezers or clothespin**
- **paper towels**
- **1 test tube**
- **2 strips of black paper or foil (approx. 5 cm x 2 cm)**
- **2 small paper clips or pieces of scotch tape**

(for the teacher)
- **several potted plants (such as geraniums) that have been prepared for this experiment or several variegated coleus plants**
- **hot plate**
- **isopropyl alcohol (70 %)**
- **2 large (1000 mL) beakers**
- **eye protection**
- **oven mitts or substitute**

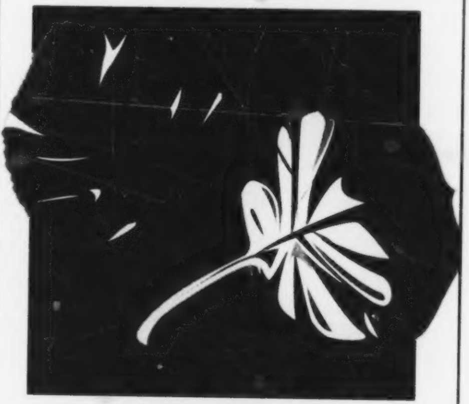
Parts B, C, D, and E: Turn on the Bubble Machine

You will need a total of 42 *Elodea* sprigs (about 6-8 cm long) from young, healthy plants to complete all of these exercises. Plan your groupings to accommodate the amount of *Elodea* that you have available. Each exercise requires the following:
- **2 wide-mouth jars or beakers**
- **2 glass funnels (short-stemmed)**
- **2 test tubes**
- **specially-prepared water**
- **pair of scissors**
- **lamp with 75 or higher wattage bulb (optional)**
- **foil or box to cover one of the beakers**
- **1 teaspoon of baking soda**
- **stirring rod or spoon**

TEACHER PRELAB PREPARATION:

FOR PART A: LEAF PORTRAITS

1. Part A requires at least two days. During this activity, students will learn the relationship between chlorophyll and the presence or absence of starch in plants. There are two ways to accomplish this. The classic procedure involves covering part of a leaf with an opaque material and leaving the leaf in light for 24-48 hours. This will remove the chlorophyll from the covered portion of the leaf. The students then compare the amounts of starch in the different portions of the leaf. An alternative is to use a plant with variegated leaves; the colored portions of these leaves contain chlorophyll, while the white parts will not.



Variegated leaves

2. Select plants that have leaves that are not too thick or too large. Geraniums work well. Divide the plants into two groups; place one group in total darkness for about 48 hours and the other group in strong light for the same period. Remember to keep the leaves from the two groups of plants separate and do not remove too many leaves from any one plant.

3. Before the students can perform the starch test, the leaves need to be prepared. First, you will need to boil the leaves in water to break the cell walls, which will make it easier to remove the chlorophyll from the leaves. To do this, fill a large beaker half full of water and place it on a hot plate. Wear eye protection! Gently drop leaves from the first group of plants into the water and boil them for five minutes. Carefully remove the beaker of water from the hot plate. Now, you will remove the chlorophyll from the leaves by placing them in warm alcohol (chlorophyll is soluble in alcohol). Turn down the heating setting and place a beaker containing 200 mL isopropyl alcohol on the plate to heat. Place the boiled leaves in the alcohol and heat them for two or three minutes. Don't boil the alcohol! Remove the leaves from the water once they have lost their green color and give them to the students. **Note**: If you plan to use a heat source other than a hot plate to heat the alcohol, use a double boiler to prevent the alcohol from contacting the flame. Turn off the flame before adding alcohol to the inner container. Keep a water bath handy to put out accidental fires. Make sure you have adequate ventilation in your room for boiling alcohol. You may want to alert your neighbors that the odor may linger. Remember

to keep students away from hot alcohol—it is highly flammable and can cause severe burns.

4. To prepare a dilute iodine solution, dissolve 2 g potassium iodide in 25 mL of water. Then add 1 g of ground iodine crystals and stir. Add water to bring the final volume of the solution to 300 mL. Store the solution in a dark brown bottle away from heat. You can supply students with individual dropper bottles containing this solution. Feel free to substitute common drugstore iodine.

FOR PARTS B-E: TURN ON THE BUBBLE MACHINE

1. To prepare the water for Parts B-E, boil tap water to remove dissolved gases. Allow the water to cool to room temperature before using. You will need at least 1 liter of this water per group for each exercise, so plan accordingly. If you do not have the facilities to boil large quantities of water, fill large containers (such as aquaria) with tap water and leave them uncovered for 24-48 hours to allow the dissolved gases to escape.
2. You should be able to submerge a funnel in the jars or beakers used in Parts B-E. The jars or beakers should be made of colorless glass or plastic. Battery jars, large mayonnaise jars, or 1000 mL beakers work well.
3. The test tubes should fit over the stems of the funnels and still allow students to cover the mouths with their thumbs. But keep in mind that smaller tubes will fill up with oxygen faster than larger tubes.
4. If the light in your classroom is not strong, supply artificial light using lamps burning 75-100 watt bulbs. The more intense the light, the faster the rate of photosynthesis. If you choose to use high wattage bulbs, such as 500 watt bulbs, be sure to protect plants from the heat by covering the lamps with blue cellophane (leave vent holes to allow the heated air to escape). Protect eyes from strong light and keep combustible materials away from the lamps.
5. For best results, place *Elodea* plants in 2.5% solution of baking soda about an hour before the students use them. Don't use this procedure for the plants to be used in Part D.
6. In Part C, the students need to cover one of the beakers to keep it out of the light. You can supply boxes for this purpose, or cut pieces of foil to the right size. You might also consider having the students place their beakers in a dark closet or cabinet. You should decide on a method before the students begin Part C.
7. For Part E, you will need to decide where students should place their set-ups in relation to the light source. Designate distances for artificial light sources. If you are using natural light, you should find places in strong light and in shade where the students can put their beakers.

ACTIVITIES:
PART A: LEAF PORTRAITS
I. EXPLORING IN SMALL GROUPS

During this activity, students will test for the presence of starch, a substance produced using the products of photosynthesis. The procedure for this activity will differ depending on the type of plant that you use. If you use variegated leaves, students will not need to cover the leaves with opaque material. They will, however, need to draw the leaves before and after they perform the starch test. They should indicate on their drawings which portions of the leaves contain chlorophyll and which do not. With non-variegated leaves, you will need to direct the students in covering the leaves with foil or carbon paper. Use scotch tape or lightweight paperclips to avoid damaging the plants.

Once the students have prepared the plants, ask them to predict what will happen to the leaves that are kept in the dark for 48 hours as opposed to the ones kept in bright light for that time period.

When the plants have sat for the appropriate time in the lighted and unlighted locations, prepare the leaves for the iodine test following step 3 in the *Teacher Prelab Preparation.* Then have the students conduct the iodine test using the following procedure:

- Carefully drop iodine solution onto the leaf to cover the entire surface and let it rest for several minutes undisturbed.
- Use tweezers, a clothespin, or tongs to transfer the leaf to another dish. Wait for about ten minutes and then rinse the leaf with water. Remove the leaf from the water, place it on a folded paper towel, and examine the leaf.
- Repeat procedure with second leaf provided by your teacher.

II. DEVELOPING IN A LARGE GROUP

Gather students as a whole class and discuss their findings. Here are some questions that may be helpful:

1. What did the iodine test reveal about the starch content of the leaves from the plant stored in the dark? the plant stored in bright light?
2. What did you predict would happen to each leaf? How did your prediction compare with the actual results?
3. Which parts of the covered leaf gave a positive starch test?
4. What can you infer from the results of the test?

PART B-E: TURN ON THE BUBBLE MACHINE
I. EXPLORING IN SMALL GROUPS

During these activites, students will examine the production of oxygen during photosynthesis. Students will perform the same basic procedure, changing variables slightly each time to see how they influence photosynthesis. The procedure for Part B is described in full; the variations for Parts C-E follow after:

- Label the beakers as "A" and "B" and fill each about halfway with the specially-prepared water. Add half a teaspoon of baking soda to each beaker and stir.

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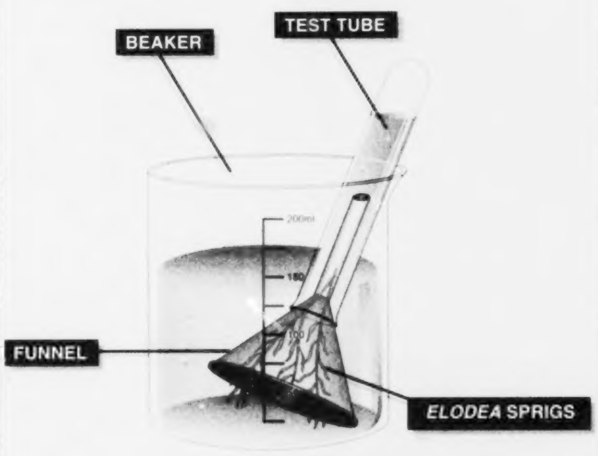
- Carefully place a funnel upside-down in each beaker of water. If the tip of the funnel is above the level of water in the beaker, add more specially-prepared water until the tip is at least 1 cm below the surface of water.
- Cut off about 1 cm from the bottom part of *Elodea* shoot. If possible, cut the plants while they are under water. Place five or six shoots of *Elodea* in the wide part of funnel in Beaker A so that the cut ends are at the top. Do not place any plants in Beaker B.
- Fill a test tube completely with the specially-prepared water. Covering the mouth of the test tube with your thumb, turn the tube upside-down and place it over the stem of the funnel, using your thumb to prevent losing any of the water from the test tube. Repeat the process for the second beaker. Place both beakers in the lighted area designated by your teacher. Predict what will happen in the two beakers. Observe every three minutes for a total of 15 minutes or longer, if necessary.
- For Part C, place five or six *Elodea* shoots in both beakers. Put Beaker B in strong light. Cover Beaker A to prevent light from getting to it. Leave the plants undisturbed for 30 minutes and then observe.
- For Part D, don't add baking soda to Beaker A. Place five or six *Elodea* shoots in each beaker. Place the beakers near a light source at distances designated by your teacher.
- For Part E, add five or six *Elodea* shoots in each beaker. After the plants have sat near a strong light source for two minutes, count the number of bubbles given off in one minute. Count twice more at five minute intervals.



Laboratory set-up for Part B: Turn on the Bubble Machine

II. DEVELOPING IN A LARGE GROUP

After each activity, gather the students as a class and discuss their findings. For Part B, discuss what they observed and how it compared to their predictions. Would placing more *Elodea* shoots in a beaker affect the results? For the ensuing sections, focus on observations and encourage the students to compare the results obtained in each activity to those observed in the previous activities. Why have things changed and what does this tell them about photosynthesis?

BACKGROUND INFORMATION:

Plant leaves can take many shapes and sizes. Some are flat, some curled, and the leaves attached to carnivorous plants, such as venus fly traps, can even be dangerous to insects. But despite their differences, plant leaves all have one primary function—to make food for the plant. Unlike humans and other animals, who rely on existing organic materials for food and energy, plants are autotrophs. Autotrophs use inorganic raw materials to create their own food supply, and subsequently provide the organic components that fuel the entire food chain.

The process by which plants produce food is called **photosynthesis**. Photosynthesis occurs in leaf structures called **chloroplasts**, which contain **chlorophyll**, a pigmented molecule that absorbs light. As with many scientific terms, the word "photosynthesis" tells us a lot about the process. "Photo" is the Greek word for light, while "synthesis" comes from the Greek word meaning "to put together." During photosynthesis the chloroplasts use light to construct carbohydrates from water and carbon dioxide. The process is very efficient—even though each chloroplast only absorbs one to five percent of the total light energy, photosynthesizing plants manage to "fix" over 200 billion tons of carbon annually.

Photosynthesis occurs in two stages. During the photochemical phase, the energy of light is captured by chlorophyll molecules and used to split water into its molecular components, hydrogen and oxygen. Because water is such a stable molecule, its splitting also produces a tremendous amount of energy, which is stored in a high energy molecule known as ATP. The second phase uses the energy stored in ATP to bond hydrogen to carbon dioxide in a process known as **reduction** or "fixing." The product is a three-carbon carbohydrate, which the plant uses to continue the carbon fixation process and to manufacture glucose, a six-carbon sugar. Many plants then convert glucose into starch, a large organic carbohydrate polymer. Carbohydrates, such as sugars and starches, serve as an energy source for the plant. The sole by-product of photosynthesis, oxygen, is released into the environment. The oxygen produced by photosynthesis is not wasted; in fact, the oxygen that we breathe comes primarily from plants.

Because the second phase of photosynthesis requires the products of the first phase, the process needs light to occur. In this activity, students will examine how depriving plants of light prevents photosynthesis. They will also test for starch, a material produced using the products of photosynthesisis. Finally, they will examine the production of oxygen from photosynthetic activity.

PRACTICAL APPLICATIONS:

Knowledge of factors that affect photosynthesis are useful to anyone growing plants, whether you are a farmer, own a nursery, or just want to grow a plant in a flower pot.

NOTE:

You may want to modify some of these activities to utilize the materials available to you.

ADAPTED FROM:

Bishop, D. D. (1986). "Production of oxygen." *Science Activities*, 23 (1). 18-21.

Laetsch, Watson M. (1979). *Plants: Basic Concepts in Botany*. Boston, MA: Little, Brown, and Company, pp. 224-32.

Lyon, J. F., Hinckley, C. P., & Protopapas, P. N. (1985). *Laboratory manual for life science*. Dubuque, IA: Kendall/Hunt, pp. 75-80.

Morholt, E., & Brandwein, P. F. (1986). *A sourcebook for the biological sciences*, (3rd ed.). San Diego: Harcourt Brace Jovanovich.

Newman, B., & Kramer, S. (1992). *Hands-on life science activities for middle school*. Annapolis, MD: Alpha Publishing, pp. 185-86.

Steiner, E., Sussman, A. S., & Wagner, W. H., Jr. (1965). *Botany laboratory manual* (2nd ed.). New York: Holt, Rinehart and Winston, pp. 105-18.

DEVELOPMENT QUESTIONS:

1. What is inside the bubbles produced by *Elodea*?
2. How can you tell when a chemical reaction is taking place?
3. What is the purpose of a control in an experiment?
4. Describe a recipe for photosynthesis.
5. Why place the plants underwater during Part B?

APPLICATION QUESTIONS:

1. How would you prove that some plants do or do not carry out photosynthesis?
2. A plant is planted in a pot of soil. It is weighed and set in the sunlight. After one year, the plant has grown and is weighed again. It has increased in weight by 50 g. Where has this extra weight come from?

ASSESSMENT:

1. A submerged aquarium plant gives off 40 bubbles of gas every minute when placed at a distance of one meter from a lamp with a 100-watt bulb. What different things can you do to increase the rate of bubble formation?
2. How could you prove what the products of photosynthesis are?

EXTENSIONS:

1. Continue observing the experiments for two or more days. Does anything change?
2. Do Part C using red, green, blue, and clear cellophane to cover the plant.
3. Test how varying the amount of carbon dioxide available to the plant affects photosynthesis.
4. Devise a way to collect the gas produced by photosynthesis.
5. Test the relationship between the temperature of the water and the rate of gas formation in aquarium plants.

Where Does Carbon Come From?

Students will investigate the action of plant enzymes on starch to find evidence of carbon in plants. First, they will create a barley extract and, using a dilute iodine solution, test for the presence of starch. They will also test for glucose, which is produced when the barley enzymes interact with starch. Finally, they will observe how yeast feeds on glucose, releasing carbon dioxide gas into the air.

TIME NEEDED: One to two hours

OBJECTIVES: At the end of this activity, students will be able to identify the basic requirements for and products of photosynthesis.

PROCESSES: Observing, inferring

MATERIALS: (for each group)

15 five-day old barley seedlings
fine sand (approx. 1/2 teaspoon)
60 mL distilled water
mortar and pestle
cheese cloth (cut to cover the funnel in a double layer)
funnel
beaker, flask, or jar (larger than 50 mL)
2 small flasks, beakers, or jars
well plate or 14 small cups
container of water for rinsing
container to catch waste water
4 droppers
marker or glass-marking pencil
graduated cylinder (10 mL or larger)
3 plastic spoons
starch (0.25%) solution
dilute iodine solution in a dropper bottle
timing device (like a wall clock)
eye protection
dried yeast (1/2 teaspoon)
2 paper cups

(optional)
14 test tubes
test tube rack or substitute
test tube clamp or substitute
10 mL Benedict's solution
glucose test paper strips

(for the teacher)
heat source
double boiler or substitute for water bath
eye protection

TEACHER PRELAB PREPARATION:

1. You need to germinate the barley seeds five days before your class is scheduled to do the activity. To germinate the seeds, wrap them in a moist paper towel and place them in a closed container. Do not use

pearlized barley. It will not germinate because the seed coat and part of the endosperm have been removed.

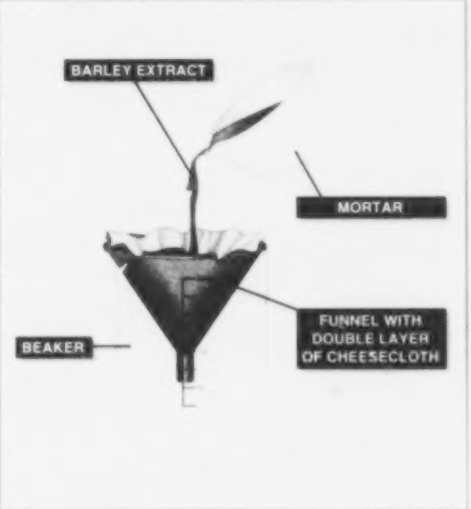
2. Once the students have extracted the enzymes from the barley seedlings, use the extract immediately. Storing the extract will inactivate the enzymes.
3. To prepare a dilute iodine solution, dissolve 2 g of potassium iodide in 25 ml of water. Add 1 g of ground iodine crystals and stir. Add water to bring the final volume of the solution to 300 mL. Store the solution in a dark brown bottle away from heat. You can supply students with individual dropper bottles containing this solution.
4. The optional portion of this activity requires 14 test tubes per group. If you do not have enough test tubes to perform this activity for every class, consider modifying the procedure so that students take readings at 10-mintue intervals. You can also use glucose test strips to test for the presence of glucose.
5. If you choose to do the optional activity, set up a water bath for the Benedict's test before the students arrive. Make sure that the bath will hold at least 16 test tubes. Keep oven mitts or other protection ready to handle hot glass. You may have to refill the water bath as the water evaporates.Warn students to keep Benedict's solution away from eyes, face, skin, or clothing and to wear eye protection when handling it.
6. If you do not plan to do the optional portion of the activity, instruct your students to do the yeast portion of the activity after they perform the starch tests.

Activities:

I. Exploring in Small Groups

The students will extract enzymes from barley seedlings and then use the enzymes to break the starch into sugar. One way to organize this activity is to have half of each group test for presence of starch using the iodine test, while the other half conducts the Benedict's test for glucose. For the iodine test, ask the students to do the following:

- Place about 15 barley seedlings (leaves and roots removed) in a mortar. Add about 1/2 teaspoon of fine sand, and 30 mL of distilled water. Grind carefully until all the seedlings are crushed.
- Place a double-layer of cheese cloth over the funnel, hold the funnel over the beaker or flask, and pour the barley extract from the mortar through the cheese cloth.



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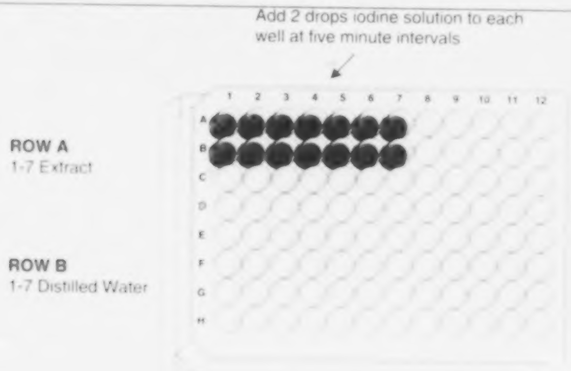
- Organize your equipment to ensure that you will be able to repeat steps efficiently and quickly. Label two small, clean beakers A and B. Pour about 10 mL of the extract into Container A. Pour about 10 mL of distilled water into Container B. Add 10 ml of starch solution to each container. Label the droppers A and B. Label one row of a well plate A and another row B. Then mark each well in the labeled rows 1-7. Use Dropper A to place 5 drops of liquid from Container A into the seven marked wells in Row A. Rinse the dropper thoroughly. Repeat the procedure for the solution in Container B, using Dropper B and Row B.
- You are now ready to begin the test. Carefully place two drops of iodine solution in depressions A1 and B1 and observe. Wait 5 minutes and then add 2 drops of iodine in depressions A2 and B2. Repeat this process, at 5-minute intervals, until you have added iodine solution to all seven depressions. After each iodine addition, record what happens in each depression. What does this tell you about the starch content of the solutions?
- Mark 2 paper cups A and B. Once the iodine test indicates that the starch is no longer present, pour the contents of Container A into Paper Cup A. Fill the cup halfway. Do the same with the solution in Container B. Add 1/2 teaspoon yeast to each cup and observe.

For the optional activity, have your students do the following:

- Label two test tubes with your group ID number. Then mark one test tube A and the other test tube B.
- Wear eye protection when handling Benedict's solution. Pour 5 mL of Benedict's solution into each tube. Using Dropper A, add eight drops of liquid from Container A into Test Tube A. Use Dropper B to add eight drops of liquid from Container B into Test Tube B. Rinse both droppers. Take your test tubes to the water bath and leave them in the bath for three minutes. Record what happens. Be careful when removing hot test tubes from the water bath.
- Repeat the procedure every five minutes for a total of 30 minutes.


Add 2 drops iodine solution to each well at five minute intervals
ROW A
1-7 Extract
ROW B
1-7 Distilled Water
1
2
3
4
5
6
7
8
9
10
11
12
A
B
C
D
E
F
G
H

Well plate set-up for starch test.

II. DEVELOPING IN A LARGE GROUP

Gather students as a whole class and discuss their findings. Focus on how the different solutions reacted to the different tests. What do the enzymes from the barley extract do to the starch?

BACKGROUND INFORMATION:

One of the products of photosynthesis is glucose, a simple six-carbon sugar. Rather than using the glucose itself for energy, many plants convert glucose into starch. Starch is another type of carbohydrate; plants store starch in the leaves and other plant tissues as a source of energy. The energy is only produced by the action of enzymes, special substances that catalyse chemical reactions in living organisms. Enzymes break down the starch into glucose, producing energy as each bond is broken. Germinating barley seedlings, for example, possess a number of enzymes to digest stored starch. The glucose produced by the enzymes gives the seedlings the energy they need to grow. Among the enzymes found in barley seedlings are alpha-amylase, beta-amylase, and maltase. Amylase, for example, changes starch into maltose, and maltase then converts maltose into glucose.

Glucose, in turn, is consumed by yeast for energy, producing carbon dioxide gas. Recall that carbon dioxide is one of the reactants in photosynthesis. Here, we saw that starch was converted to glucose by the action of enzymes in barley seedlings, and that yeast then breaks down glucose into carbon dioxide. Carbon, therefore, must be present in plant tissues.

DEVELOPMENT QUESTIONS:

1. Where do baby plants get their food before they grow leaves?
2. Why do plants need leaves to grow?
3. Do plants contain carbon? Explain how you know.

APPLICATION QUESTIONS:

1. What would happen to a plant that failed to make starch?
2. What would happen if one of enzymes were missing?

ASSESSMENT:

1. What would happen if you used uncrushed barley seedlings in the activity?
2. Where do plants get their carbon?

EXTENSIONS:

1. Explore the action of enzymes obtained from other seeds on starch.
2. Investigate the effect of temperature on enzymatic action.

Pond Bottom

Students will create artificial pond bottoms and observe what happens.

TIME NEEDED: One hour with repeated observations over time.

OBJECTIVES: After completing these activities, students will be able to describe how biogenesis and diagenesis operate in the production of oil.

PROCESSES: Observing, identifying, predicting.

MATERIALS:

clear plastic 2-liter soft drink bottles
soil tamper (sturdy rod)
soil from a garden, woodland, or field)
water from a pond, stream, puddle, or aquarium
carbonate source (2.5 to 3 g of calcium carbonate, ground egg shells, or seashells)
organic source (20 x 25 cm finely shredded newspaper, sawdust, shredded leaves, or roots)
sulfate source (2.5 to 3 g of calcium sulfate, magnesium sulfate, shredded cooked meat, or hard-boiled egg yolk)

ACTIVITIES:

I. EXPLORING IN SMALL GROUPS

To create the pond bottoms, have the students do the following:

- Remove any stones, twigs, or lumps from the soil.
- Mix the organic, carbonate, and sulfate sources together in a handful of soil. Pack the soil mixture in the bottom of a plastic bottle using the tamper to remove trapped air. The soil should be 3 cm deep at the bottom.
- Add more plain soil to the bottle, using the tamp to remove air bubbles. Continue until the column is packed to within 5 cm of the top of the bottle.
- Cover the surface of the soil with water about 2.5 to 3 cm deep. Seal the top of the bottle tightly.
- Place the bottle in a window that receives indirect sunlight, or in a north-facing window.

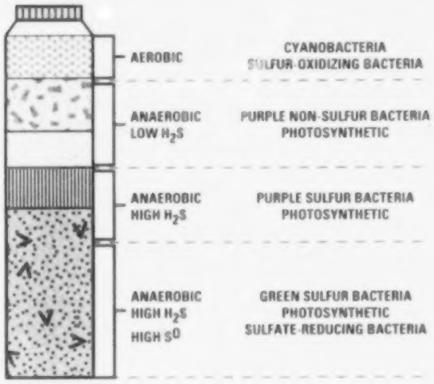
II. DEVELOPING IN A LARGE GROUP

Over a period of time, have the students observe any changes and discuss them as a large group. Compile the changes into a list for the class.

BACKGROUND INFORMATION:

The "pond bottom" produced by your students in this activity is actually a scientific device. Developed by Sergei N. Winogradsky, a late nineteenth century microbiologist, the Winogradsky column aids scientists studying the action of sulfur bacteria. The column promotes the growth of a variety of autotrophic bacteria, which grow in different regions of the column.

The graphic below shows where the growth will occur in the bottle. The successsional biogenesis sequence in the artificial pond bottoms may take anywhere from six weeks to two months to occur. Warner conditions will speed the process. Green algae should appear in three days to one week. Sulfate-reducing bacteria, which produce black spots of hydrogen sulfide, will turn the entire bottle black after anywhere from six days to four weeks. Photosynthetic purple-sulfur bacteria appear as reddish-purple spots 5-7 cm from the bottom of the bottle between three and six weeks. They disappear shortly thereafter. Purple non-sulfur bacteria form a rust colored zone in the upper third of the bottle after around 17 days. The various microorganisms feed on the organic material, decomposing it when oxygen is available. This process is known as biogenesis, which is one of the first steps in the formation of coal and oil. Coal develops from plant material and oil from animal components. Biogenesis is followed by diagenesis. Heat increases due to pressure during diagenesis, which causes microorganismic activity to cease.


AEROBIC
CYANOBACTERIA
SULFUR-OXIDIZING BACTERIA
ANAEROBIC
LOW H_2S
PURPLE NON-SULFUR BACTERIA
PHOTOSYNTHETIC
ANAEROBIC
HIGH H_2S
PURPLE SULFUR BACTERIA
PHOTOSYNTHETIC
ANAEROBIC
HIGH H_2S
HIGH S^0
GREEN SULFUR BACTERIA
PHOTOSYNTHETIC
SULFATE-REDUCING BACTERIA

PRACTICAL APPLICATIONS:

This activity shows students that the soil and water are not lifeless parts of ecosystems. Soil and water are full of microorganisms that can have a dramatic affect on the environment

NOTES:

A control is important in any experiment, so please remember to create one for this experiment. In addition, you may want to set up bottles ahead of time. Consider staggering the initial starting days so that students will have the chance to observe different stages of biogenesis over a shorter period of time.

ADAPTED FROM:

Corner, Thomas R. (March 1992). "Ecology in a Jar." *The Science Teacher*, pp. 32-36.

Skoog, G., & Lien V. (1988). *Strategies for teaching life science*. Lubbock: Texas Tech University.

DEVELOPMENT QUESTIONS:

1. How would you account for the changes you observed?
2. Why is it always important to have a control in an experiment?

3. How do the changes vary over time?
4. Why was it necessary to remove as much air as possible from the soil?

APPLICATION QUESTIONS:

1. How do living things affect the soil column?
2. How do non-living things affect the changes the living things made?

ASSESSMENT:

Predict what would happen to these columns after one year. How about after 10 years?

EXTENSIONS:

To give the students more experience with how microorganisms interact with different organic materials, try varying the soils, water samples, organic, carbonate, and sulfate sources used. To show how specific pollutants can affect this system, try adding fertilizers or incesticides to one of the bottles. You can also see whether different wavelengths of light or different temperatures affect the activity of microorganisms.

OVERVIEW TEACHER BACKGROUND INFORMATION
ENERGY AND WORK—RESULTS OF FORCE AND MOTION

In daily conversation, how do you use the words "work" and "energy"? When you think of work, you probably think about your job. When you are teaching, you are working. But when you are enjoying a sport, reading a good book, or practicing a hobby at home, you probably do not believe that you are working—these activities are too much fun to be called work. Usually, work implies obligation, something that we must do, not something that we *want* to do.

Energy, on the other hand, is required for everything that we do, whether we are working or playing. For example, when you bounce happily out of bed in the morning, you might say that you are full of "energy." But when you are feeling tired or low, you might say that you do not have the energy to do anything. We think of energy as something that lets us do different things. We need energy to work, play sports, or practice a hobby. We need energy to do just about anything, whether we call it work or not.

These popular ways of conceptualizing work and energy are not very different from the way scientists defined these terms centuries ago. A few hundred years ago, though, scientists found that these definitions failed to explain adequately the different ways that humans, animals, and machines worked and used energy. Work and energy were complicated when applied to human activities; the actual processes used by machines were much more simple. In addition, scientists needed a way to measure phenonmena, as short mathematical statements could say more than thousands of words. These equations could predict the future; they could tell how, when, and where something would happen. Equations offered scientists remarkable possibilities. By developing equations into precise, scientific laws, scientists could understand and explain more complicated aspects of nature and make better predictions. But creating these laws required precise definitions of the phenomena that scientists wanted to explain. The popular defintions of work and energy, therefore, needed to be changed into measureable definitions.

How Do We Get Energy?

All around us we can find machines doing jobs. Automobiles and buses carry us along the road. In our homes, washing machines and air conditioners make our lives easier. Each of these machines needs fuel to be able to do its job. Automobiles are powered by gasoline or diesel fuel. Machines in our home run on electrical energy, produced by electric generators powered by the steam heated by coal, oil, or even nuclear matter. What we may not realize is that machines are not the only things that require fuel to do their jobs. When animals work, they need to eat to replenish the energy that they use. Even a small job, such as lifting a pound of coffee up onto a pantry shelf, requires us to expend some energy. The question is whether there is a way to measure the amount of fuel expended to do a given job.

Scientists began to get a better idea of how energy is produced by observing simple engines. Because engines require measurable amounts of fuel to do a job, scientists could easily observe whether there was a relationship between the amount of fuel

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expended and the job performed. For example, scientists could set up an experiment to measure how much fuel was required to raise a pound of coffee one foot. Such experiments revealed that the bigger the job, the more fuel a machine needs to perform it. In fact, they discovered that fuel expenditure was directly proportional to the amount of work required to accomplish a job. If the small engine used 10 drops of fuel to raise a pound of coffee one foot, it took 20 drops of fuel, or twice as much fuel, to raise the coffee two feet, or twice as high. And scientists found that this same correlation could be found in humans and other animals. When an animal works, it consumes fuel proportional to the amount of work accomplished.

Do All Jobs Need Fuel?

You have just seen that when machines or animals do work, they consume fuel proportional to the amount of work accomplished. But do all jobs require fuel? For example, when you stand holding something heavy, you quickly become tired. Certainly the job requires you to expend fuel. But if you set the load on a table, the parameters of the job change; the table expends no energy to support the object. This example reveals one of the problems with the popular definitions of work and energy. Just because humans use fuel to accomplish a given task does not mean that the job necessarily requires fuel. Scientists discovered that certain tasks always require fuel, whether they are performed by animals or machines. When we raise a load, wind a clock spring, or stretch a rubber band—in other words, when we use force to put something in motion—we need fuel to accomplish the task. But when we need to hold something in a fixed position, whether it be a heavy parcel or a taunt rubber band, fuel is not required. A table can push up on a parcel with just enough force to support it, or two nails can keep a rubber band taunt. In these cases, force is applied, but no motion occurs. Similarly, no fuel is required when there is motion without force. Newton defined inertia as the tendency of objects to resist any change in motion. Objects traveling at a constant speed will continue to travel at that speed if no forces act on them, and hence, this motion requires no fuel.

What is Work?

We can conclude that two physical quantities can help us determine whether a job will require the expenditure of fuel: force and motion. If a job involves the application of force and the force puts something in motion, fuel has been expended. Building on this evidence, scientists developed a more accurate definition of work. Work is done if and only if fuel is used to do a job. Or, to phrase the definition more scientifically, **work is the transfer of energy through motion—the energy expended when you apply force to an object is transferred into motion**. The trouble with this definition is that it still does not allow us to measure work. To put measurable quantities into the definition of work, scientists returned to a simple job where work was done: an engine lifting a load a spec-

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ified height. Let's say that when an engine lifts one pound one foot, it has done one pound-foot of work. You can use this standard to help measure the work needed to do larger jobs. For example, if the engine lifts two pounds one foot, it has done two pound-feet of work. Similarly, raising one pound six feet reqiures the engine to do six pound-feet of work (lifting the load six feet means the machine must do one pound-foot of work six times). We can even use this standard to help us evaluate more complex jobs. For example, how much work does the engine do when it raises two pounds three feet? To figure this out, divide the process into two smaller jobs. First, lift one pound three feet, and then lift another pound three feet. Each time, you do three pound-feet of work, which means to complete the entire job you will do six pound-feet of work.

These examples reveal that the total work done always depend on two values: the amount of force exerted (ie. the weight of the object) and the distance over which the force is applied. In mathematical terms, scientists define work as

$$W = F \times d$$

As with energy, work is measured in joules. One joule is equal to one newton-meter (very similar to the pound-foot value used in the example). Recall that a newton is the amount of force needed to accelerate one kg at a rate of one m/s. One joule, then, is the amount of work done when a force of one newton acts over a distance of one meter.

As Work Is Done, in What Forms Does Energy Appear?

When work is done, the machine or person doing the work uses fuel. According to the popular definition of energy, the person or machine also loses energy—we get tired and do not feel like doing any more work. Where has the energy gone? Does it just disappear? Obviously, the popular definition of energy is as scientifically inaccurate as the popular definition of work. To take a closer look at energy, let's examine what happens in a variety of situations where work is done. For example, let's imagine that we have a sailing ice-sled equipped with steel runners resting on the surface of a perfectly frictionless frozen lake. A wind applies a constant force of 100 pounds to the sails, and the sled begins to accelerate. If the wind keeps blowing, the sled will move faster and faster. In this case, though, the wind stops after the sled has traveled 20 feet, which means that the wind did 200 pound-feet of work. But what happened to the sled in terms of energy? Before the work was done, the sled was at rest. After the work was done, the sled was moving at some high speed. The energy expended by the wind was transferred into the sled's motion. We would say that the sled has kinetic energy. Kinetic energy is an extremely common and powerful type of energy transfer, and scientists have used Newton's second law of motion and the definition of work to measure it. **Kinetic energy** depends upon the mass and the velocity of the moving object. The greater the mass, or the greater the velocity, the more kinetic energy an object has. Scientists express this relationship mathematically as

$$K = mv^2/2$$

where m=mass and v=velocity.

Now let's return to our simple engine, which can lift a pound of coffee up onto shelves in a pantry. When the engine lifts the coffee up to a shelf five feet off the floor, it accomplishes five pound-feet of work. What happens to the coffee in terms of energy? Before the work was done, the coffee was at rest, and afterwards, the coffee is still at rest. But the energy did not disappear; if you push the coffee off the shelf, gravity accelerates it faster and faster until it hits the floor. The work we did was stored as we moved the coffee, and was only exhibited as motion when the coffee fell. Scientists call this type of energy **gravitational potential energy**. The pound of coffee has no visible energy when it sits still, but can produce a tremendous amount of kinetic energy when gravity is allowed to do work on it. Gravitational potential energy is a form of **potential energy**, which we define as the energy stored in an object. Another type of potential energy is **elastic potential energy**, which we can best observe in springs or rubber bands that have been streched taunt. When they are released, the potential energy is converted into kinetic energy.

Another form of energy is produced by friction. If we pull a box weighing 50 pounds 10 feet across the floor, we will do 500 pound-feet of work. But when we are done, the box remains motionless and gravity cannot work on it because of the force exerted by the floor. However, if you touch the bottom of the box after moving it, you will discover that it is hot. The floor that you dragged the box over will also be slightly warmer. In this case, the work you did overcoming the friction exerted by the floor was transferred into heat, or **thermal energy**.

These examples have shown us that as work is done, energy appears in different forms. Energy can be stored as a form of potential energy, such as gravitational or elastic potential energy. Work can produce motion, resulting in kinetic energy. And work can also produce heat, or thermal energy. While our examples have illustrated jobs involving the production of only one type of energy, most situations are more complex. For example, consider an automobile traveling up a hill. The car itself builds gravitational potential energy as it travels higher and higher up the slope. Simultaneously, the car is in motion, possessing kinetic energy. Although most of the heat in the engine is produced by the burning gasoline, some of the thermal energy is produced because of friction between the moving parts. As the generator stores electrical energy in the battery, the battery gains electrical potential energy (sometimes called chemical energy).

Energy and Money?

One way to help us understand the way energy is transferred is to compare energy to something we all know and love: money. Before we explore this analogy, let's look at a simple example. If we roll a ball along the floor and up an incline, the ball will eventually come to a stop and begin to roll back down the incline. How do work and energy relate in this example? Setting the ball in motion requires us to do work on the ball. The ball transfers this work into kinetic energy. Because the friction between the ball and the floor is minimal, the ball continues to roll with the same kinetic energy until it reaches the incline. But as it climbs, the ball slows down. The pull of gravity converts the ball's kinetic energy into gravitational potential energy. When the ball stops, all of the kinetic energy has been converted into gravitational potential energy. That is, until gravity again begins to do work on the ball. The ball rolls down the incline, and the potential energy is converted back into kinetic energy.

Can we explain the energy transfer in this example by comparing it to money? Well, in a way, money in your pocket is like kinetic energy—you can set it in motion by spending it. And money in the bank is like potential energy—the money is there, but you can't put it to use until you convert it to kinetic money. When you do work, you gain kinetic money, in the same way that the ball gained kinetic energy when you did the work required to roll it up the incline. As you put the money in the bank, you neither gain nor lose money—the money simply changes form. You still have the same amount of money, whether it exists as potential money or kinetic money. Energy works the same way. The ball rolling up the incline still has the same amount of energy as it had when it was rolling along the flat surface. The energy simply exists in a different form.

Energy, like money, remains constant through an interaction. To understand this, think about what happens when you give money to someone. From your perspective, the money has been lost. But the other person has gained the money. The net gain and loss in this interaction is zero. If you think about it, we never really lose money, unless we destroy it somehow. The money just changes forms or goes somewhere else. We can use a simple experiment to show how energy works the same way. Set a ball on the floor, and roll another ball so that it hits it. The collision causes the ball you rolled to stop, while the other ball rolls away. In this case, the stationary ball borrowed the kinetic energy that you gave the rolling ball. Energy does not need to be in the same form to be transferred in this way. For example, the action of a slingshot converts the elastic potential energy stored in the catapult into the kinetic energy exhibited by the projectile.

The point is, work is simply a **transfer of energy**. When something does work on something else, the energy produced is transferred to that object in some form, whether it be potential energy, kinetic energy, thermal energy, or chemical energy. And during an interaction, the energy generated by the initial work remains constant—as with money, you cannot gain or lose energy. Scientists call this the **Law of Conservation of Energy**. Regardless of the interaction occurring, whether we are rolling a ball across a floor or driving a car up a hill, the toal amount of energy in the system will never change.And whenever it appears that energy has been lost, scientists look for another form of energy.

Project Teacher Materials—First Edition—Eighth Grade

What Happens to the Energy of a Pendulum?

Students will study pendular motion as an introduction to the Law of Conservation of Energy.

TIME NEEDED: One hour

OBJECTIVES: At the end of this activity, the student will be able to distinguish between the popular and scientific defintions of work, fuel, and energy.

PROCESSES: Observing, inferring

MATERIALS: (for each group)

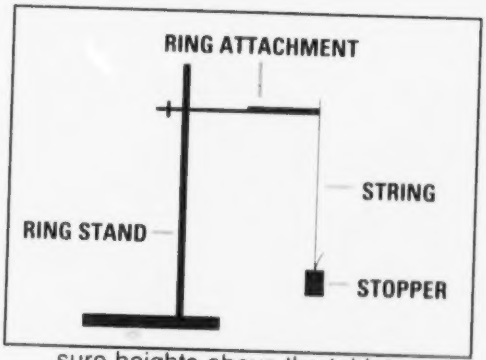
ring stand and ring
2 metersticks
2-hole, medium rubber stopper
100 cm string
masking tape

ACTIVITY:

I. EXPLORING IN SMALL GROUPS

The students will assemble the pendulum and record the starting and ending heights of the pendulum as it swings. Ask them to set up the apparatus as follows:

- To assemble the pendulum, refer to the diagram below. First, connect the string to the rubber stopper. Then tie the string to the clamp and ring stand.
- With masking tape, mark the center of the stopper. Use this line to measure heights above the tabletop.
- Move the stopper away from the cross arm. Measure the height of the stopper above the table. Record this measurement. Release the stopper and let it swing. Observe carefully and measure the height the stopper reaches at the opposite end of its swing. Record this measurement. Repeat these steps several times, each time starting the stopper at a greater height and recording the corresponding ending height.



II. DEVELOPING IN A LARGE GROUP

Have groups report their results. Average the class data and use this to guide class discussion. Some questions may be helpful:

1. On a single swing, is the ending height of the stopper exactly the same as its starting height? Explain

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why or why not.

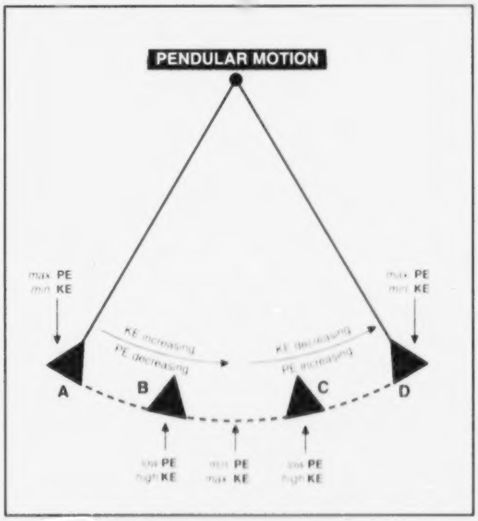
2. What happens when the starting height is higher than the cross arm?
3. What is the highest ending point that the stopper will reach? What happens if the starting point is higher than that point?

BACKGROUND INFORMATION:

The Overview Teacher Background Information sheet entitled "Energy and Work—Results of Force and Motion" will give you a working idea of the difference between the popular and scientific defintions of work and energy. The sheet also outlines some of the common forms of energy that your students will investigate during these activities. Feel free to introduce material from these sheets as you see fit.

How much do you believe in physics? In Carl Sagan's novel, *Contact*, a religious leader tests the "faith" of the main character (a prominent physicist) through an experiment in pendular motion. The main character holds the ball of a large pendulum under her chin and releases it, standing her ground to demonstrate her confidence that the ball will not smack her in the face on its return swing. Pendular motion illustrates the law of conservation of energy, which states that energy may change form, but cannot be created or destroyed under ordinary conditions.

During pendular motion, the total energy in the system remains constant. Before the pendulum is set in motion, the stationary ball contains a certain amount of potential energy. When the ball is released, the potential energy is converted into kinetic energy until, at the bottom of the swing, the kinetic energy is at its greatest level and the potential energy is at its minimum. As the ball makes its upswing, the force of gravity converts the kinetic energy back into potential energy until the ball is once again at the top of its swing and possesses the greatest amount of potential energy. The energy continues to change forms as the pendulum moves back and forth, always retaining the same total amount of energy in the system.



PRACTICAL APPLICATIONS:

These same ideas can be applied to sports that require a swinging motion. Have students use the scientific terms learned in this experiment to describe the energetics of the swinging motions used in certain sports, such as golf or baseball.

ADAPTED FROM:

Aldridge, Bill G.; Crow, Linda W.; and Aiuto, Russell (1993). *Energy Sources and Natural Fuels, vol. 1.*

Washington, D.C.: National Science Teachers Association.

Aldridge, Bill G. (1993). *Science Interactions*. Westerville, OH: Macmillan/McGraw-Hill.

Thompson, Marilyn; Smith, Richard G; and Ballinger, Jack T. (1993). *Merrill Physical Science*. Westerville, OH: Macmillan/McGraw-Hill.

DEVELOPMENT QUESTIONS:

1. At what point along a single swing does the stopper have the greatest kinetic energy? The least kinetic energy?
2. At what point does the stopper have the greatest potential energy? The least potential energy?

APPLICATION QUESTIONS:

1. Under what conditions can the cross arm prevent the stopper from returning to its maximum potential energy?
2. When are the potential energy and the kinetic energy of the stopper both at zero?

ASSESSMENT:

Have students describe the motion of a roller coaster in terms of potential and kinetic energy.

EXTENSIONS:

Have students vary the pendulum bob and string length to determine how this affects pendular motion.

Who Did More Work?

Students will discover that not all work is the same—that work depends upon the amount of force exerted and the distance covered. They will ascertain how much work they each perform when walking up a flight of stairs.

TIME NEEDED: One hour

OBJECTIVES: At the end of this activity, the student will be able to distinguish among the common and scientific meanings of fuel, work, and energy.

PROCESSES: Observing, inferring, predicting

MATERIALS: (for each group)

meter stick
flight of steps
watch with second hand
bathroom scale

TEACHER PRELAB PREPARATION:

1. Before attempting this activity with a class, find a stairway that will not be used heavily during the experiments.

ACTIVITIES:

I. EXPLORING IN SMALL GROUPS

Show the students how to use a bathroom scale to measure the weight in newtons of one volunteer. If the scale reads in kilograms, the students will need to convert the weight to newtons (use 1 kg = 9.8 N). Then have them do the following:

- Use the meterstick to measure the vertical height of one step. Multiply the height of one step by the number of steps. Determine the total height in meters.
- Using the stopwatch, measure how long it takes a person to walk up the flight of steps.
- Record the name of the walker, the person's weight (force) in newtons, the distance covered, and the time taken by the person. You will use these values to calculate the work done by each person and the value for work per unit time. A data table containing these columns may be helpful.

Name	Force (N)	Distance (m)	Work (j)	Time (s)	Work/Time (j/s)

II. DEVELOPING IN A LARGE GROUP

As a large group, calculate the work done in walking up the steps in joules. Then have the students calculate the work divided by time produced in walk-

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ing up the steps. Were their predictions accurate? Some questions may help:

1. Which person exerted the greatest force?
2. Which person did the most work? Why?
3. Which person generated the greatest j/s in walking up the steps? Why?
4. If the person with the least amount of weight walked quickly up the steps, what would happen to the total sum of j/s generated?
5. If the person with the greatest amount of weight walked slowly up the steps, what would happen to the total sum of j/s generated?
6. What factors determine the number of j/s produced in walking up the steps?
7. Which person could probably produce the most j/s? Explain your answer.

BACKGROUND INFORMATION:

In this activity, students will do work on themselves to investigate the factors that influence how much work is done in a system. Each student will travel the same distance up the stairs. But they are not all working the same—heavier students will do more work, because they must exert more force to cover the same distance.

Often, students have trouble understanding how they can tire doing something without doing any work. For example, holding books for a period of time will make their arms sore, but they are not doing work on their books. Rather, they are working their muscles—each fiber in the muscle tissue is contracting and relaxing as the students hold the books.

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DEVELOPMENT QUESTIONS:

1. Why do we have to separate the ideas of work and energy from what happens inside living things when doing jobs?
2. List several kinds of jobs that could be done without using fuel.
3. How do jobs differ?

APPLICATION QUESTIONS:

1. What would be a good definition of work?
2. When must fuel be used to do a job?

ASSESSMENT:

When would a scientist say that no work is done on a job?

EXTENSIONS:

Repeat the experiment using more stairs or stairs inclined at a steeper angle.

Down the Hill

Students investigate potential and kinetic energy by studying cart motion.

TIME NEEDED: One hour

OBJECTIVES: After completing this activity, students will be able to distinguish between the common and scientific meanings of fuel, work, and energy.

PROCESSES: Observing, inferring, measuring.

MATERIALS: (for each group)

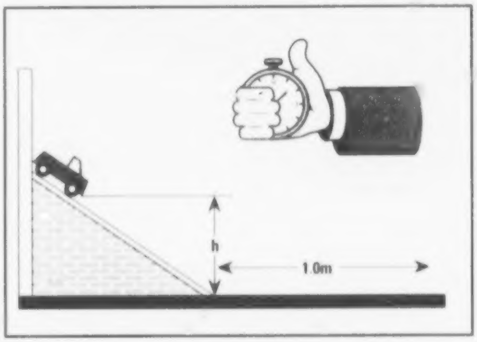
meterstick
stopwatch or timer
cart or rolling car
0.5 m to 1.0 m ramp (constructed of board, cardboard, or other suitable material)
1.0 kg mass
masking tape
several textbooks

ACTIVITIES:

I. EXPLORING IN SMALL GROUPS

Provide several different types of materials so that students can construct their own variations on a basic inclined plane. This will give the class more opportunities to observe how different conditions affect the motion of the car. Have the students do the following:

- Construct an inclined plane using the materials provided.
- Tape the 1 kg mass to the rear of the car. Place the car at the top of the ramp and measure the height of the ramp to the front of the car. Then place a piece of masking tape one meter away from the bottom of the ramp.



- Allow the car to roll down the ramp. Time how long it takes for the car to roll to the masking tape. Record the value, and continue rolling the car down the ramp until you get the same value consistently. Observe the car each time and describe how it moves along the track. When is it moving fastest?

II. DEVELOPING IN A LARGE GROUP

Have students describe the motion of the car. Introduce the concepts of kinetic energy and potential energy, and discuss the exercise in these terms. Some questions may help:

1. Explain your observations in terms of potential and kinetc energy. When does the car have the most potential energy? When does the car have the most kinetic energy?
2. What happens to the kinetic energy and potential energy as the car rolls down the ramp? Across the floor?

BACKGROUND INFORMATION

This activity allows students to investigate the relationship between potential energy and kinetic energy. As with pendular motion, energy is not lost during this experiment, but is converted into another form. Some of the factors acting on the car include gravity (which converts the potential energy that the car possesses at the top of the incline into the kinetic energy exhibited when it is released) and friction (produced as the car rolls along the floor and by air resistance).

PRACTICAL APPLICATIONS:

This can be easily applied to designing cars and other devices that need to move quickly. What factors slow the car as it rolls along? Can you think of ways to reduce the effect of these factors?

NOTES:

Students will need some guidance to use these terms properly. Be sure to help them understand how these physical quantities apply to the experiment that they have performed.

ADAPTED FROM:

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DEVELOPMENT QUESTIONS:

1. Phil and Linda have identical small cars. Phil drives on the freeway at a greater speed than Linda. Which car has more kinetic energy?
2. Phil and Linda are driving at the same speed, but in opposite directions on the freeway (Linda's car is heading south, Phil is going north). Which car has more kinetic energy?

APPLICATION QUESTIONS:

1. Two kids are competing in a soap box derby by rolling two carts down a hill. One of the carts is heavier than the other. Will this affect the outcome of the race? If the heavier car is placed higher on the hill, will this affect the outcome?

ASSESSMENT:

When a football player kicks a ball, describe the energy involved.

EXTENSIONS:

Have the students change the size and weight of the cart to determine how these variables affect the experiment.

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Lifting Heavy Objects

Students investigate the use of a hydraulic jack and how it relates to force and energy.

TIME NEEDED: One hour

OBJECTIVES: After completing this activity, students will be able to distinguish between the common and scientific meanings of fuel, work, and energy.

PROCESSES: Observing, inferring, measuring

MATERIALS: (for each group)

hydraulic jack (car jack, fitted with a base plate and a load-lifting plate)
spring balance

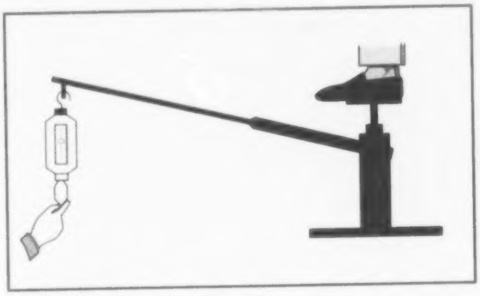
TEACHER PRELAB PREPARATION

1. Be sure you are familiar with how to operate a hydraulic jack. Most cars come with one. You can ask students to bring one from home to ensure that each student will have the opportunity to use one.
2. Be sure students are familiar with how to use a spring balance.

ACTIVITIES:

I. EXPLORING IN SMALL GROUPS

Demonstrate how to use the jack. Work the jack up and down and use it to lift one student standing on the lift plate. Then, ask the students to use a spring balance to measure the force needed to lift the student.



II. DEVELOPING IN A LARGE GROUP

As a class, discuss the results. How does the jack work? How much force did it take to lift the student? Some questions may be helpful:

1. Describe the jack. How does it appear to work?
2. How is the shaft extending from the smallest cylinder attached to the jack?
3. What does the shaft extending from the largest cylinder do?
4. Which cylinder is longer?
5. How can you get the most efficient stroke action from the jack?
6. How many strokes does it take to extend the shaft from the longer

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cylinder? Explain.

PRACTICAL APPLICATIONS:

Learning how to use a car jack properly can help you in auto emergencies. What other ways might you be able to use a car jack?

NOTES:

Be sure students are wearing flat shoes before they stand on the jack.

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Aldridge, Bill G.; Crow, Linda W.; and Aiuto, Russell (1993). *Energy Sources and Natural Fuels, vol. 1.* Washington, D.C.: National Science Teachers Association.

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Thompson, Marilyn; Smith, Richard G.; and Ballinger, Jack T. (1993). *Merrill Physical Science.* Westerville, OH: Macmillan/McGraw-Hill.

DEVELOPMENT QUESTIONS:

1. How many times greater is the lifted weight than the force applied to the handle?
2. How does the handle of the jack affect how much work is done?

APPLICATION QUESTIONS:

1. What is the approximate distance from the pivot to the other end?
2. What is the approximate distance from the pivot to the shaft of the smaller cylinder?
3. How many times bigger is the first length than the second length? Why might this be?
4. Can you guess what is inside the jack? Explain your answer?

ASSESSMENT:

Ask the students to think of an example of an object that moves without force being applied in the direction of the motion. Explain this process in energetic terms.

EXTENSIONS:

Ask students to describe how a person walks in terms of force and motion.

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Hol(e)y Rocks

Students will investigate the concept of porosity and explore how it enables a material to act as a reservoir for fluids.

Time Needed: One hour

Objectives: At the end of this activity, students will be able to describe how oil is produced, how it migrates, and how petroleum companies detect it.

Processes: Observing, inferring, measuring, communicating, classifying, predicting, controlling variables, interpreting data, developing models.

Materials: (for each group)

2 250 mL beakers
100 mL graduated cylinder
100 mL glass beads or BB's
100 mL marbles or bearings
100 mL sand
100 mL gravel
100 mL silt (dry powder, such as cement mix)
hand lens
water
hand samples of coarse sandstone, fine sandstone, limestone, and shale

Teacher Prelab Preparation:

1. A local florist or a craft supply store may be a good source for large quantities of marbles and glass beads. Glass beads are used in distillation columns at refineries. They are also available from scientific supply companies.
2. You may be able to collect rock samples locally. If not, try to purchase them from governmental road and construction departments, local contractors, or at scientific supply companies.

Activity:

I. Exploring in Small Groups

Students will create their own soil layers and determine how oil collects in the different layers. Instruct your students to do the following:

- Fill one beaker to the 100 mL marker with marbles. Fill the other with glass beads.
- Measure 100 mL of water with the graduated cylinder. Add the water to the beaker of marbles to bring the water level to 100 mL. Measure how much water remains in the cylinder. Subtract this level from 100 to determine how much water you poured into the beaker. Record the values. Repeat the above steps for the beaker of glass beads.
- Clean out your beakers, and fill one of the beakers to the 20 mL marker with sand. Measure 20 mL of water

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with the graduated cylinder. Pour the water into the beaker and record the new water level in the beaker. Subtract 20 (the volume of water) from the new water level to find the volume of sand in the beaker. Then subtract this value from 20 (the original volume of sand and air) to determine how much air was contained in the pore spaces of the sample. Record all your calculations. Repeat this procedure for the gravel and silt.

II. DEVELOPING IN A LARGE GROUP

Let the students share and discuss their results. Then pass out the samples and have the students observe them using the hand lenses. Have the students place each sample in an equal amount of water. Observe the rocks the next day to see which ones soaked up the most water. Use the following qeustions to guide the discussion.

1. Why were you able to add water to a space already filled with material?
2. Why were you able to add more water to certain materials?
3. Define the word "pore" and explain how it is relevant to this activity.
4. How do the samples differ from the other materials that you worked with in this lab? How are they similar?
5. Predict how well each of the samples would be able to absorb and hold water or other fluids.

BACKGROUND INFORMATION:

Many people believe that water, petroleum, and other fluids found beneath the surface of the earth collect in large pools or underground chambers. While this can happen, most petroleum deposits fill in the pore spaces found between underground sedimentary rock formations. This investigation relates directly to investigations performed in the Texas SS&C eighth grade Blocks I (Streams) and II (Disappearing Acts).

Chemical and physical weathering gradually break up rocks on the earth's surface into particles, which settle to form sediment. Some sediments consist of the hard shells produced by plants and animals. These organic materials may be consolidated intact or broken down into particles. Sediment size may range from quite large to microscopic, as the chart below indicates.

Sediment	Particle Diameter
boulder	more than 256 mm
cobble	256 mm to 64 mm
pebble	64 mm to 4 mm
granule	4 mm to 2 mm
sand	
very coarse	2 mm to 1 mm
coarse	1 mm to 1/2 mm
medium	1/2 mm to 1/4 mm
fine	1/4 mm to 1/8 mm
very fine	1/8 mm to 1/16 mm
silt	
coarse	1/16 mm to 1/32 mm
fine	1/32 mm to 1/ 256 mm
clay	smaller than 1/256 mm

Erosion transports the sediments to different locations. Wind and water carry the sediments along as they move, and when they slow down, the sediments

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drop in a new location. This process is called **deposition**. Over time, some deposits are buried by other layers of sediments. The pressure of these new layers cements together the lower layers to form a type of rock known as sedimentary rock. This rock appears solid, but the spaces between the particles of sediment remain. These spaces are known as **pores.** Pores can be filled with air, water, or in some cases, petroleum. If the pores are connected to each other, the rock becomes permeable and fluids can flow through it. The students will investigate permeability in a subsequent activity.

PRACTICAL APPLICATIONS:

Helping the students understand the concept of porosity will make it easier for them to comprehend permeability. By grasping these concepts, students will be able to understand how rock can hold fluid, and how the fluid can thus migrate from place to place within the earth's crust without flowing in underground rivers or streams. Porosity is also relevant to acoustics, packaging, building materials, farming, and housewares.

NOTES:

You may wish to measure the silt into a graduated cylinder rather than a beaker to ensure that the two substances will combine properly.

ADAPTED FROM:

Lord, J. & Braaten, G. (1990). *Teaching about energy* (Part 2). [The energy '90s teacher's resource book]. Santa Monica, CA: Enterprise for Education.

Petroleum Extension Service. (1979). *Fundamentals of petroleum*. Austin: University of Texas.

DEVELOPMENT QUESTIONS:

1. How can solid rock store fluids?
2. Why can certain rocks store more fluid than others?

APPLICATION QUESTIONS:

1. While observing a container of pond water for an experiment, a group of students accidentally spilled the water. Some of the pond water spilled on the desk and the rest spilled on the cement floor. How could the students save as much of the pond water as possible?
2. A thirsty explorer happens upon a water well, but is unable to reach the water. Then she rememberd the fable about the thirsty crow that dropped rocks into a pitcher until it could reach the water. She gathered as many stones as she could find and dropped them into the well. To her dismay, the well was soon full of stones and she still could not reach the water. What went wrong?

ASSESSMENT:

Have the students observe two new rock samples. Ask them to predict which sample will hold the most water and devise a method to test their hypotheses. Ask them to explain why their predictions were or were not correct.

EXTENSIONS:

Test how different rocks absorb different fluids, such as cooking oil.

I've Got Connections

Students will investigate how permeability and porosity enable a material to serve as reservoir for fluids. In Part A, **Connections**, students will explore how water is absorbed by different types of foam. In Part B, **Degree of Connectivity**, students will test sediment samples to discover which is the most permeable. Finally, in Part C, **Real Rocks**, students will apply what they have learned about porosity and permeability to study how fluid collects in sedimentary rocks.

TIME NEEDED: One hour

OBJECTIVES: At the end of this activity, students will have learned more about how oil is produced, how it migrates, and how petroleum companies detect it.

PROCESSES: Observing, inferring, measuring, communicating, classifying, predicting, controlling variables, interpreting data, developing models.

MATERIALS: (for each group)

Part A: Connections
- **hand lens**
- **small piece of impermeable foam (about 2" x 2" x 1")**
- **small piece of permeable foam (about 2" x 2" x 1")**
- **shallow dishes**
- **medicine dropper or pipette**
- **stop watch**

Part B: Degree of Connectivity
- **250 mL graduated cylinder**
- **water**
- **gravel, sand, and silt samples**
- **small pieces of screen or filter paper**
- **funnel**
- **stop watch**

Part C: Real Rocks
- **stop watch**
- **3 250 mL beakers**
- **100 mL graduated cylinder**
- **water**
- **cooking oil**
- **small samples of sandstone, limestone, and shale (2 pieces of each per group)**
- **stop watch**
- **medicine dropper or pipette**

TEACHER PRELAB PREPARATION:

1. Appropriate impermeable foams include urethane foam (commonly used for upholstery) or ethylene foam (look for this in sewing departments and craft stores, as it is commonly used to make cushions and small pillows). Test the foam to make sure it is impermeable before

using it in the lab.

2. Cut pieces from plastic sponges to obtain pieces of permeable foam. Test the pieces to make sure that they will render the desired results. You may need to rinse permeable foams first to prepare them for use.
3. Label the impermeable foam samples as Sample #1 and the permeable foam samples as Sample #2. Try to make the pieces of foam as similar as you can. Impermeable foam is usually white and has many rather uniform small bubbles. Try to choose a sponge sample that has a similar color and texture. As an extension of the basic activity, you can provide additional sponge samples taken from other materials, including natural sponge.
4. The small pieces of screen or filter paper will keep the materials that the students will test from going through the funnels. Feel free to substitute more appropriate materials if you have them available.
5. You can probably reuse the rock samples for all of your classes. They do not need to be large and other appropriate types of permeable rock may be substituted.

ACTIVITY:
PART A: CONNECTIONS
I. EXPLORING IN SMALL GROUPS

Instruct your students to do the following:

- Use the hand lens to examine foam Sample #1 closely. Record your observations.
- Place Sample #1 in the middle of a dish. Use the dropper to drop 15 drops of water onto the middle of the top surface of the sample. Let the water and sample stand undisturbed for about three minutes. Record what happens. Leave the sample undisturbed while you complete the rest of the experiment.
- Repeat Steps 1 and 2 using Sample #2. Record your observations. Check Sample #1 again to see if anything more has happened.

II. DEVELOPING IN A LARGE GROUP

Bring the class together as a large group to share and discuss their results and observations. Use the following questions to guide the discussion:

1. How does the concept of porosity apply to each of the foam samples?
2. Both samples appear to be porous, and yet they failed to absorb the water equally. Why?
3. Describe how each sample behaved when you placed water on it. Expalin any differences in how the samples absorbed the water.
4. Define porosity and permeability. Differentiate between these definitions.

PART B: DEGREE OF CONNECTIVITY
I. EXPLORING IN SMALL GROUPS

Instruct your students to do the following:

- Cover the inside of the funnel with the screen or filter paper.
- Fill the funnel half full of gravel.
- Place the stem of the funnel into the graduated cylinder. Hold the appa-

ratus steady if necessary.

- Add 100 mL of water to the funnel, and time how long it takes to collect 10 mL of water in the graduated cylinder. Record the time.
- Repeat the procedure using sand and silt instead of gravel.

II. DEVELOPING IN A LARGE GROUP

Encourage the students to share their findings. Use the following questions to guide the discussion:

1. How does the permeability of these materials compare with the porosity data that you collected in Part A?
2. Explain why some materials are more permeable than others.
3. How are porosity and permeability related to each other?

PART C: REAL ROCKS

I. EXPLORING IN SMALL GROUPS

Instruct your students to do the following:

- Drop one drop of water on each rock sample and time how rapidly each rock absorbs the water. Record your measurement.
- Repeat the procedure with vegetable oil on a dry spot on the samples. Record your measurement.
- Use a graduated cylinder to measure 100 mL of oil or water (according to your teacher's instructions) and pour the liquid into each of the 250 mL beakers.
- Carefully drop each untested rock sample into a beaker. Put the test beakers in a place where they will not be disturbed over night.
- The following day, carefully remove each sample from its beaker. Measure the volume of the liquid using the graduated cylinder. Subtract this volume from 100 to determine how much water each rock sample absorbed.
- Drop a drop of water and a drop of oil on each sample. Record what happens.

II. DEVELOPING IN A LARGE GROUP

Encourage the students to share their findings and draw conclusions. Use the following questions to guide the discussion:

1. How well do each of the samples absorb the different fluids that you tested?
2. Why do some samples absorb fluid better than others? Do some samples do better at absorbing certain types of fluid? Explain.
3. How much water were the samples able to absorb overnight? Account for any differences.
4. Why were some of the samples unable to absorb water after soaking overnight?
5. How does particle size affect the permeability of rock?
6. How does the composition and formation of a particular rock affect its ability to act as a fluid reservoir?

BACKGROUND INFORMATION:

Porous materials contain spaces, or pores, which can be filled with air or fluid. In rock, pores are formed while the rock is formed—layers of sediment are forced together by the pressure of new sediments above them. Larger particles

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tend to create larger and more numerous pore spaces and connections. The more porous a material, and the better the connections between these pores, the more permeable the material is. Permeability measures how well fluids are able to move through a material.

Foams used in upholstery, pillows, and packing material serve as good cushions because they are porous but impermeable. The tiny bubbles of air held within the pores absorb and dissipate pressures and shocks without causing the material to lose its original shape. If the pores were connected, which would make the material more permeable, the air would eventually escape from the material, causing the material to collapse under pressure.

Porous, permeable rocks that hold oil are known as reservoir rocks. These rocks are typically found in sedimentary rock formations. Few igneous rocks have pore spaces or the proper connections between the pores. Pumice, for example, is porous, but relatively impermeable. Metamorphic rocks also contain very few pores, as the heat and pressure required for their formation typically eliminates pores.

PRACTICAL APPLICATIONS:

Porosity and permeability play an important role in the development of packing materials, building materials, specialized and protective clothing, and soils used in building, farming and gardening.

NOTES:

Feel free to modify these activities to suit your space and material limitations. Many of these activities can be performed as demonstrations if necessary.

ADAPTED FROM:

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Tissot, B.P. and Welte, D.H. (1984). Petroluem Formation and Occurence. Berlin: Springer-Verlag.

Wheeler, Robert R. and Whited, Maurine. (1981). *Oil: From Prospecting to Pipeline*. Houston: Gulf Publishing Co.

DEVELOPMENT QUESTIONS:

1. What is meant by the term porous?
2. What is meant by the term permeable?
3. Compare and contrast porous and permeable materials.
4. Compare and contrast permeable and impermeable materials.

APPLICATION QUESTIONS:

1. Why would someone manufacture a foam that was porous, but not permeable?
2. What types of sedimentary rocks would make the best and worst reservoirs for fluids? Explain why.
3. Why is it appropriate to describe impermeable foam as air bubbles surrounded by plastic?
4. Why is it incorrect to describe permeable foam as air bubbles surrounded by plastic?

ASSESSMENT:

Give the students three types of sedimentary rock samples and a variety of equipment. Ask the students to identify the best and the worst reservoir rocks. Demonstrate why they believe that their choices are accurate.

EXTENSIONS:

Have students test other types of rocks and fluids. You can also have them investigate selective permeability and impermeability.

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Migrating Fluids

Students will investigate some of the factors involved in petroleum migration. They will learn how oil migrates through different types of rock, and will explore how scientists find oil deposits deep below the surface of the earth.

TIME NEEDED: Two hours

OBJECTIVES: At the end of this activity, students will be able to describe how oil is produced, how it migrates, and how scientists detect it.

PROCESSES Observing, inferring, measuring, communicating, classifying, predicting, controlling variables, interpreting data, developing models.

MATERIALS: (for each group)

- **sandstone sample (about 4 cm in diameter)**
- **tool for boring into sandstone (table knife, screwdriver, etc.)**
- **medicine dropper or pipette**
- **beaker**
- **water**
- **clear, closeable container (collecting bottle with stopper or jar with lid)**
- **marker for temporarily marking glass container**
- **vegetable oil**
- **sand**

TEACHER PRELAB PREPARATION:

1. Photocopy the rock strata diagrams included in the background material or produce overheads of these diagrams to use during discussion.
2. You will probably not be able to recycle the sandstone samples for each class. Keep this in mind as you plan the activity for your classes. You may wish to adjust student grouping to accommodate rock sample availability.
3. Tall, cylindrical containers will make observations easier; smaller sized containers require smaller amounts of material.
4. Look for sandstone and limestone samples at masonry, landscaping, and paving companies.

ACTIVITY:

I. EXPLORING IN SMALL GROUPS

PART A: PIT STOP

Instruct your students to do the following:

- Determine which side of your rock sample is flattest. Use the boring tool to carve a small pit about the size of the tip of your little finger into the flat side of the specimen.
- Use the dropper to put five drops of oil into the pit.
- Place the sample into the beaker, pit down.

- Add water to the beaker to a level about 1 cm above the tallest part of the specimen.
- Label your beaker with your group number or names and put it in a place where it will remain undisturbed overnight.
- The next day, retrieve the beaker and record what you see.

PART B: ALL SHOOK UP

Instruct your students to do the following:

- Mark the container at about the halfway point. Use the marker to divide the two halves in half again, so that the container is now divided into fourths. Label these, from the bottom, "3/4," "1/2," and "1/4."
- Add gravel to fill the container to the 3/4 mark.
- Add water to fill the container to the 1/2 mark.
- Add oil to fill the container to the top.
- Close the container and make sure that it is tightly sealed.
- Shake the container and its contents vigorously for about 15 seconds. You can time this or simply count to 15 slowly while shaking the container.
- Place the container in a spot where you can observe it clearly for 4 or 5 minutes. Record your observations in writing or draw what you see.
- Repeat steps 6 and 7 at least three times and note how things change.

II. DEVELOPING IN A LARGE GROUP

Bring the class together to share and discuss their observations as a large group. Use the rock strata diagrams to help them apply what they have discovered to materials and processes within the earth's crust. Use these questions to guide class discussion:

Part A:

1. How did the oil get from the pit in the bottom of the rock to the surface of the water?
2. What properties of sandstone allowed the results you obtained? What would happen if other types of rock, such as limestone or granite, were used?

Part B:

1. Identify the substances in the beaker and the forms that they are in.
2. What happened to the substances when they were allowed to stand after shaking?
3. Why do these materials behave in this manner so consistently?
4. What would happen if more oil, water, or air were added to the container from the bottom? From the top?

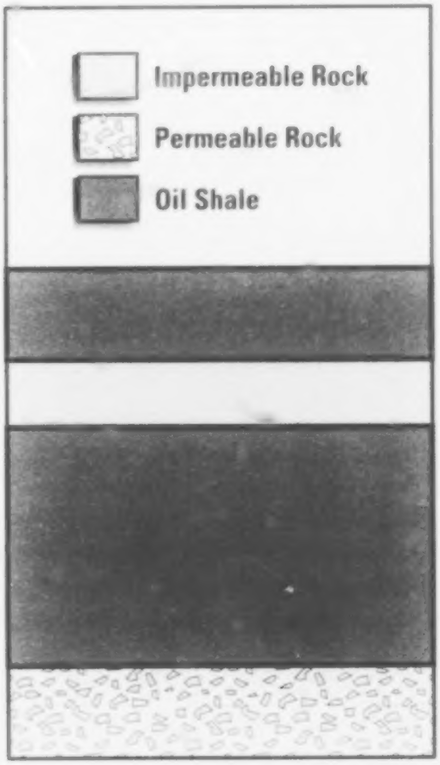
Rock Strata Diagrams

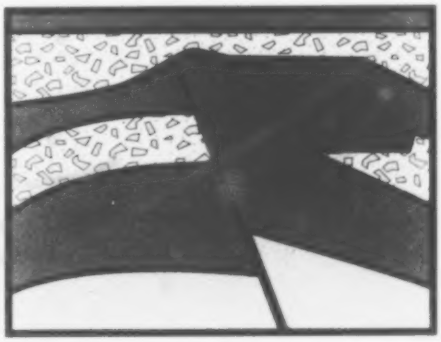
1. What would be the oil source in each of the rock strata diagrams?
2. Where would you expect to find oil in each of the rock strata diagrams?
3. What effect would impermeable rock layers have on oil migration in each of the rock strata diagrams?
4. What happens to oil when there is no impermeable rock above it?

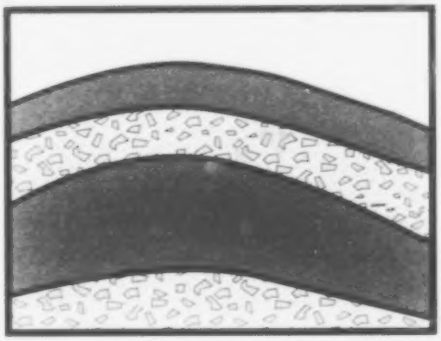
BACKGROUND INFORMATION:

Recall what you learned about photosynthesis earlier in this block. Billions of years ago, early plants discovered that they could produce extra energy by exploiting the energy of the sun. Photosynthesis caused an evolution in the production of organic matter. And when these plants died, their bodies frequently became the source of oil.

How did these organisms turn into oil? Why didn't their bodies decompose? The answer has to do with oxygen. Billions of years ago, oxygen was very rare, particularly in the environment inhabited by the first photosynthesizers: the sea. And even today, there are places where oxygen is rare, such as swamps and the deep sea. Without oxygen, as you saw in the "Rot Around the Clock" activity, organic material does not decompose. Rather, it forms a sedimentary layer, which is covered by further sediment. The pressure of the overlying sediments gradually changes the sedimentary rock into a material called kerogen. Heat within the earth and increasing pressure cooks the kerogen, transforming it into hydrocarbons. Rock where hydrocarbons are formed are known as **source rocks**.

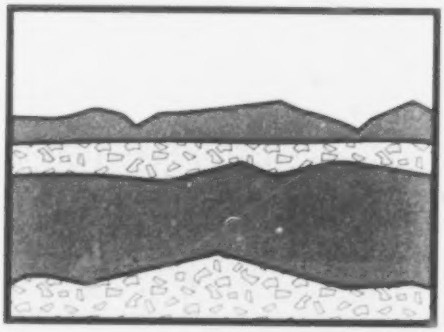


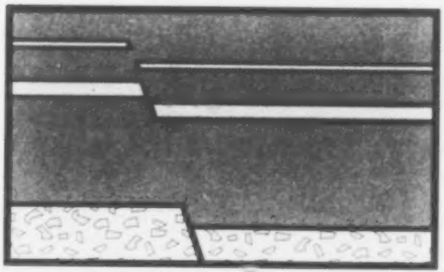




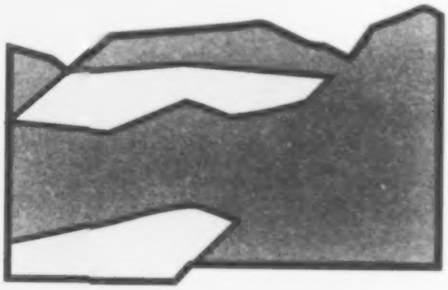
Petroleum and other hydrocarbons are produced under intense conditions. And consequently, petroleum is not discovered in the rocks where it is formed. The high pressure in the source rock causes the petroleum to escape to a neighboring layer of rock that is more permeable than the source rock. Shale is by far the most common type of source rock. Shale is made of very fine sediments, which means it usually has very low permeability. But as kerogen in the shale is changed to petroleum, pressure increases and produces small cracks in the shale, which increases the permeability of the rock.

Most sedimentary rocks underground are saturated with water, which quickly fills the porous and permeable rock. Because hydrocarbons are less dense than water, they float on top of the water. Crude oil floats on water, and natural gas floats on top of crude oil. As these substances accumulate, they are driven upward in a process known as **migration**. Migration halts when the petroleum hits impermeable rock, such as igneous deposits or layers that are neither porous nor permeable. These impermeable rock layers are called **seals** because they seal off the migration of the petroleum. The place where the oil accumulates is known as a **trap** and the rock that holds the oil in the trap is called a **reservoir**. Contrary to popular misconceptions, oil deposits are actually contained within reservoir rocks, not in cavernous structures underground. If the natural gas or crude oil do not hit a seal or trap, they are free to continue their migration to the surface. Places where hydrocarbons leak onto the ground from underground are known as **seeps**.





The key factors for a good oil well prospect are the quality of the source, reservoir, seal, and trap. When scientists look for oil deposits, they look for source rock that has high organic content and has been buried deep and long enough to change kerogen to hydrocarbons. Next, they look for porous and permeable reservoir rock above the source rock. Then, they look for an impermeable seal and irregularities in the seal that can form traps. Only if all of these conditions are present will petroleum engineers engage in the expensive process of drilling for oil.



PRACTICAL APPLICATIONS:

Understanding how and why petroleum migrates through underground materials will help students to understand some of the difficulties of and techniques developed for prospecting for petroleum. The activity will also clear up misconceptions about how fluids are held underground.

NOTES:

Many materials other than the ones suggested here may be suitable and more available to you. Test them out and use them if they work.

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DEVELOPMENT QUESTIONS:

1. Explain how petroleum moves through rock.
2. What determines the direction that petroleum will move through rock?
3. What features of underground rock formations are necessary to form a good oil deposit?

APPLICATION QUESTIONS:

1. How do the materials used in this set of activities relate to actual materials found in the ground?

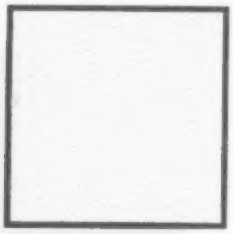
ASSESSMENT:

1. Have the students generate rock strata diagrams that demonstrate the conditions that produce good and poor sites for petroleum deposits.
2. Have students examine student-generated rock strata diagrams to determine whether they demonstrate good or poor drilling prospects.

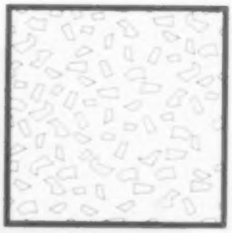
EXTENSIONS:

1. Have the students devise and create their own models to demonstrate what would happen if more oil, water, or air were added to the bottom or top of the set up used in Part B.
2. Test different kinds of rocks using the procedure in Part A.

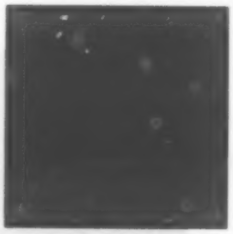
ROCK STRATA DIAGRAMS



IMPERMEABLE ROCK

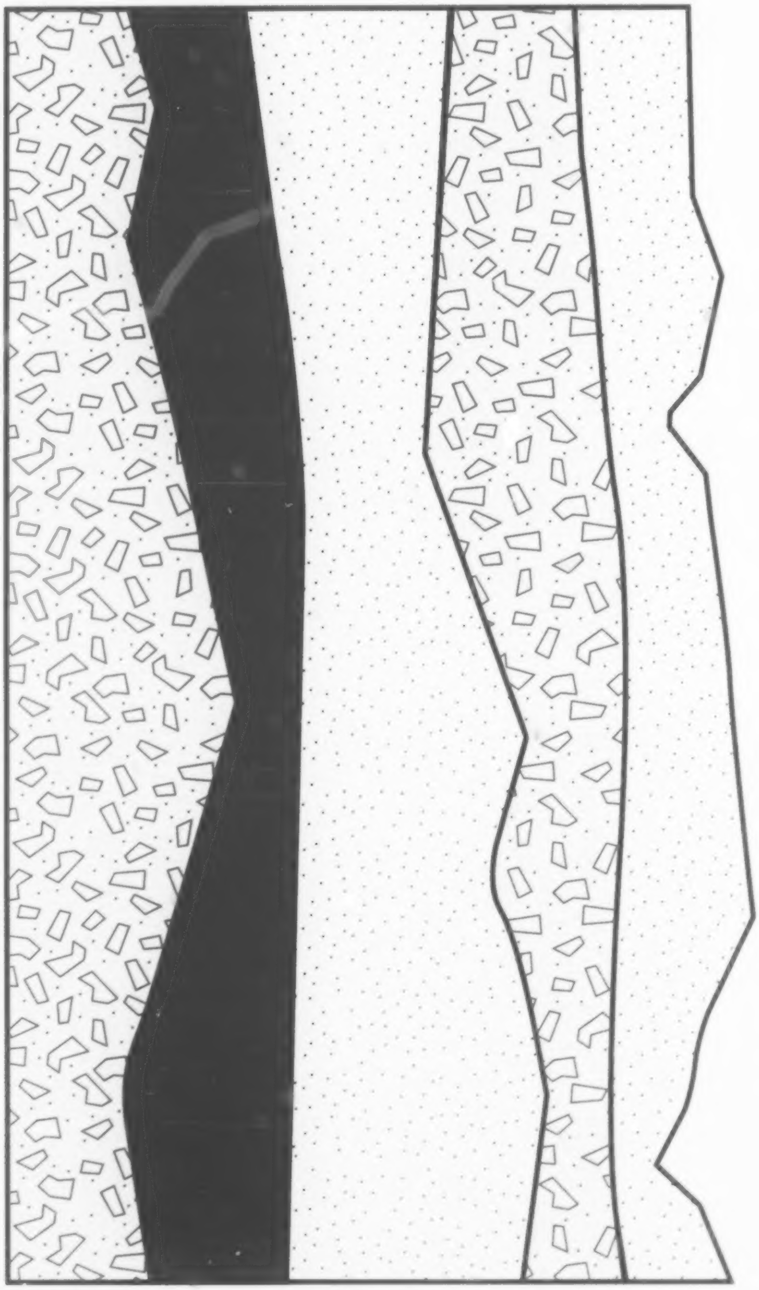


PERMEABLE ROCK

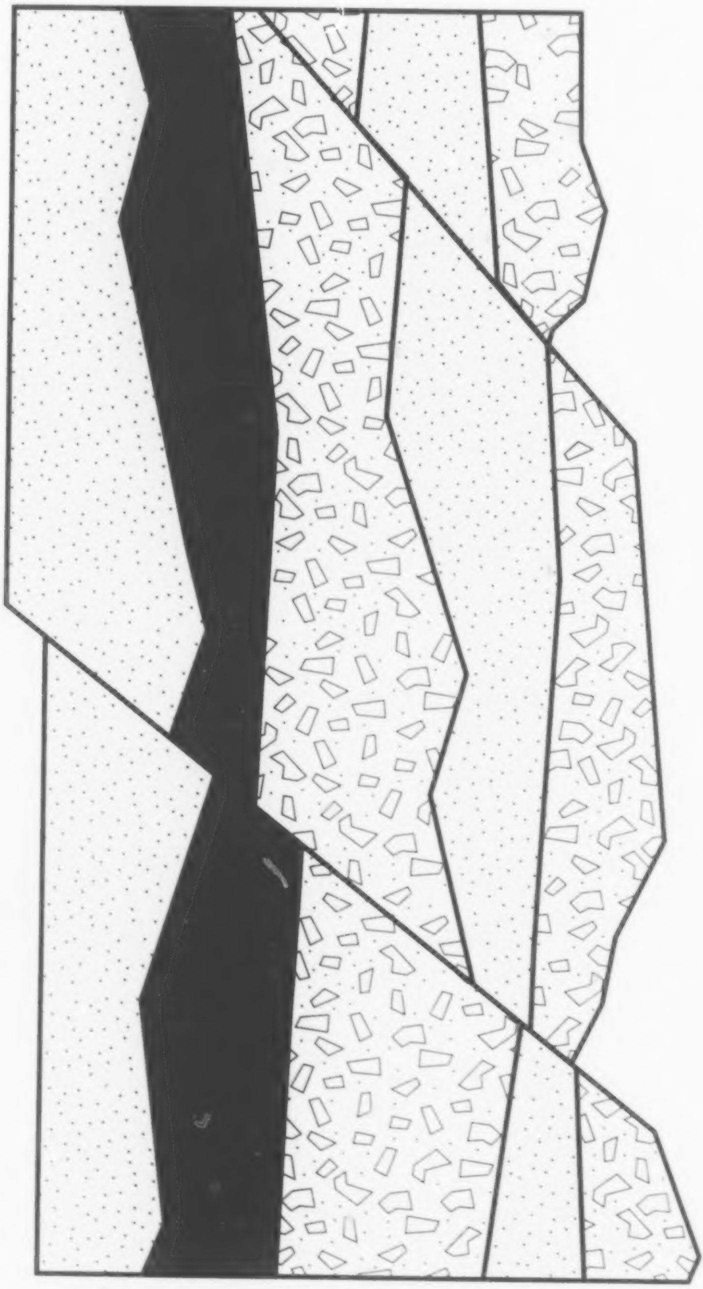


OIL SHALE

How Did It Get There from Here?
Rock Strata Diagrams



HOW DID IT GET THERE FROM HERE?
ROCK STRATA DIAGRAMS



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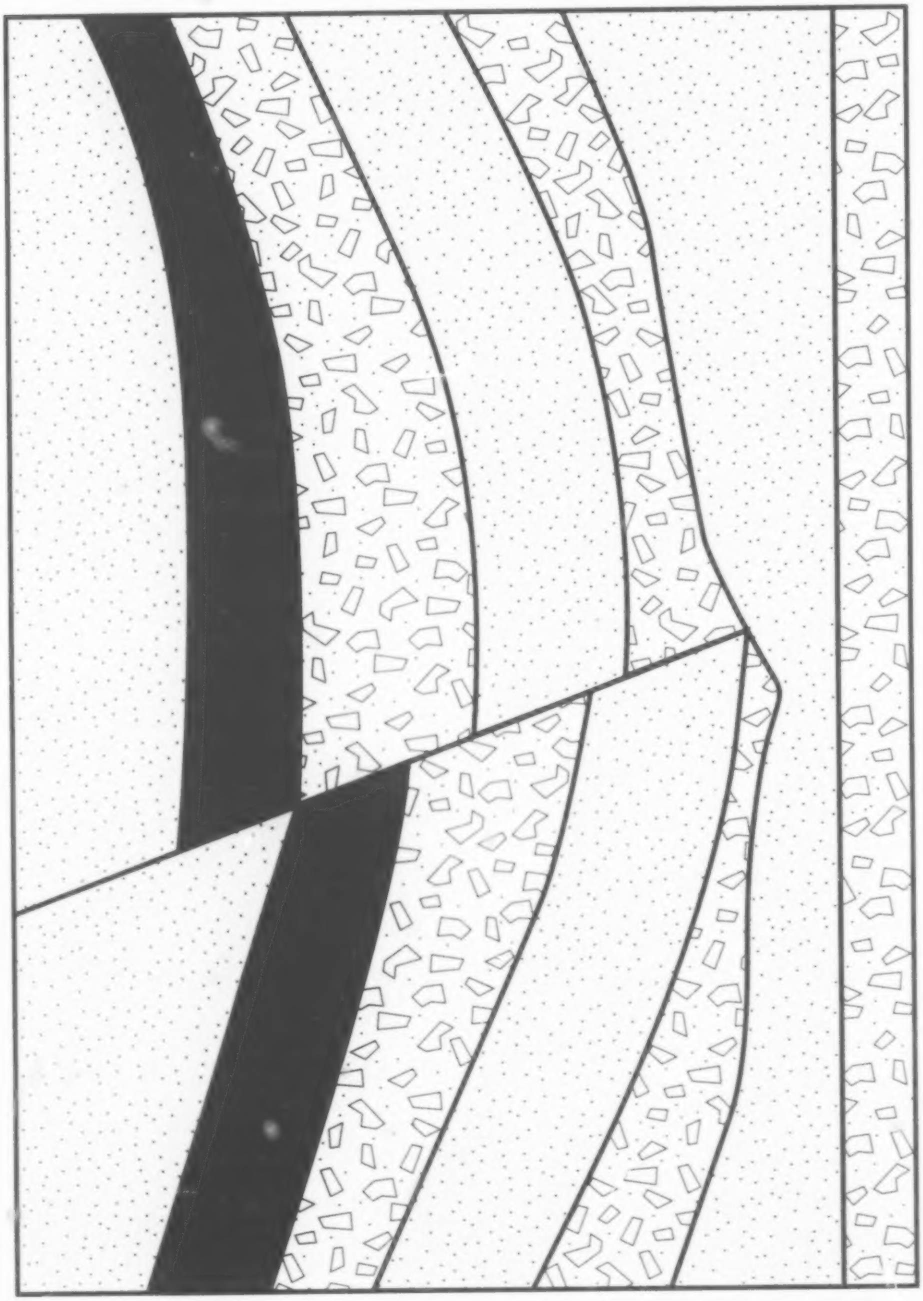
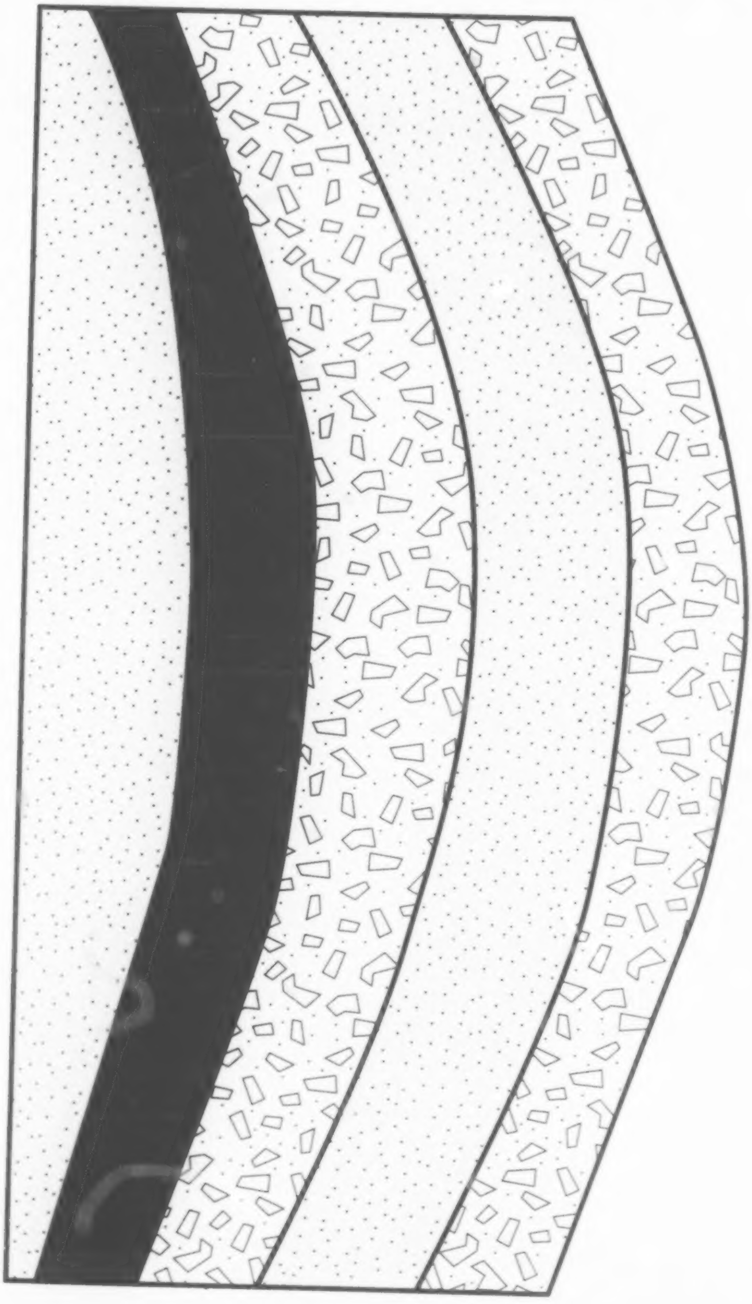
HOW DID IT GET THERE FROM HERE?
ROCK STRATA DIAGRAMS



HOW DID IT GET THERE FROM HERE?
ROCK STRATA DIAGRAMS



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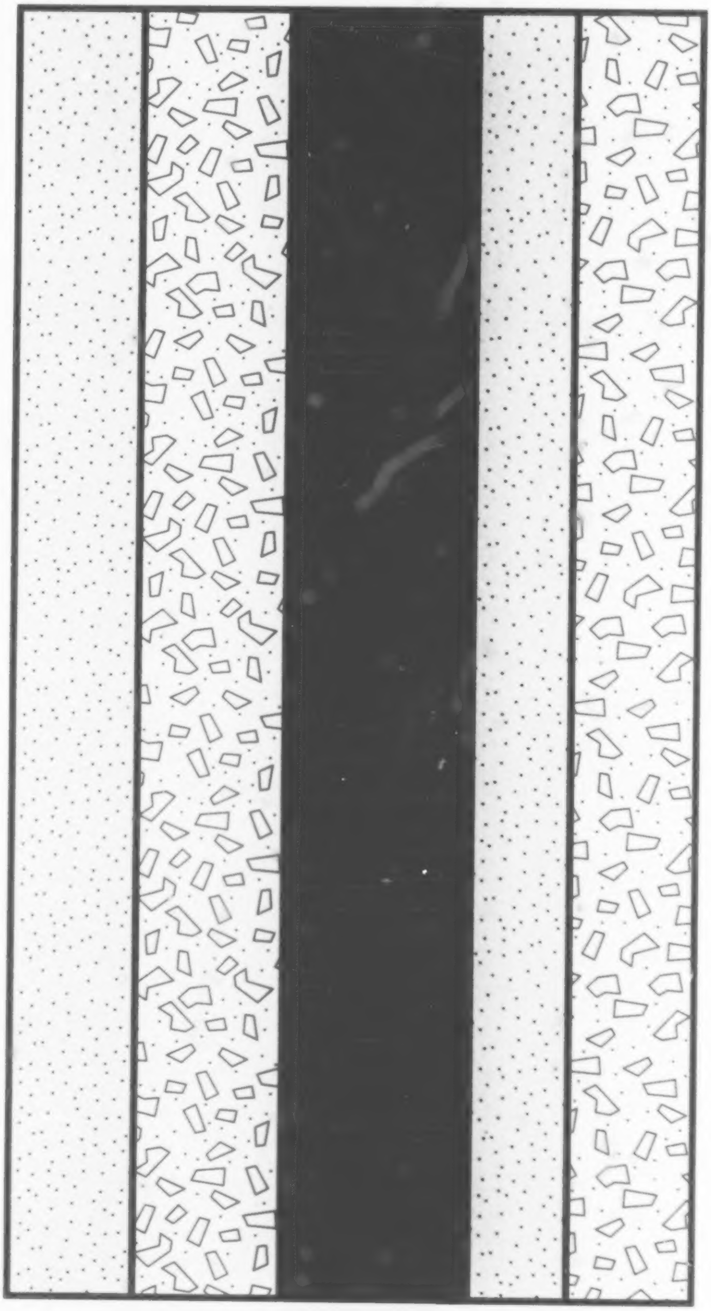
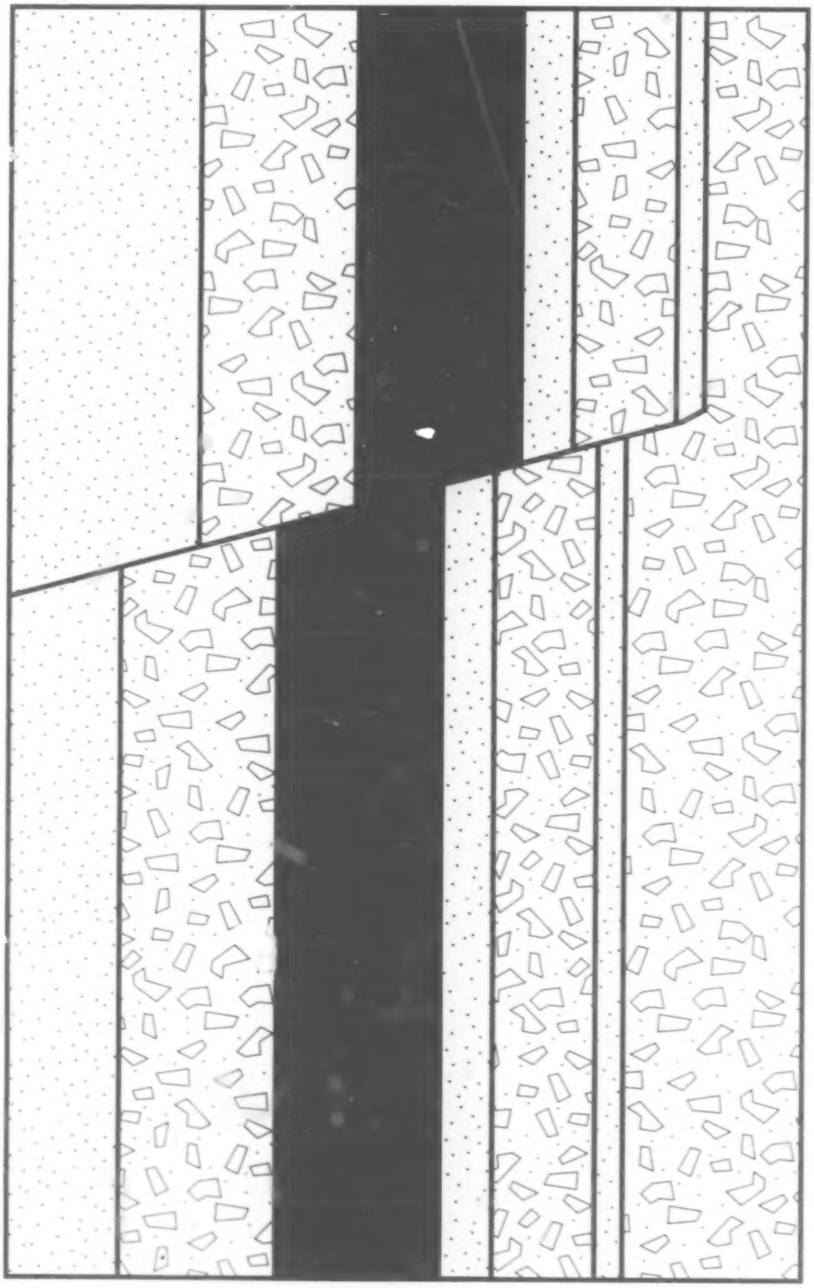


HOW DID IT GET THERE FROM HERE?
ROCK STRATA DIAGRAMS



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Where, Oh Where Can It Be?

Students will investigate some of the methods used by scientists to detect petroleum reservoirs beneath the earth's surface. Through a series of related activities, students will learn how scientists locate oil deposits. During Parts A and B, the students will work with core samples to determine the type of rock below the surface. Then, during Part C, they will conduct a sound search to locate a mock oil deposit.

TIME NEEDED: Two or three hours

OBJECTIVES: By the end of the activity, students will be able to describe how oil is produced, how it migrates, and how petroluem companies detect it.

PROCESSES: Observing, inferring, measuring, communicating, classifying, predicting, controlling variables, interpreting data, developing models.

MATERIALS: (for each group)

- **materials for strata models**
- **clear plastic drinking straws**
- **2 test tubes**
- **tamping tool (wooden dowel, pencil, etc.)**
- **shoe box with lid or other opaque container**
- **ruler**
- **sand**
- **masking tape**
- **pencil or screwdriver**
- **igneous rock sample**
- **funnel**
- **cooking oil**
- **balloon**
- **stethoscope (optional)**
- **plaster (optional)**

TEACHER PRELAB PREPARATION:

1. Two activities in this lab deal with core samples—feel free to have the students do one or both of them. For each activity, you will need to provide three materials to represent source rock, reservoir rock, and impermeable rock. While different colored sand, soils, or modeling clay seem realistic choices, you need not feel compelled to use these materials. You could, for instance, use different types of bread or different colored cake flour to achieve the same results in Part A. Tailor your models to suit your material needs. Remember, the models only need to be large enough to obtain one good core sample using a drinking straw.
2. The stethoscope and plaster are optional for Part C. Students and faculty at your school or a business in your community may be able to supply these, if a timely request is

made. Other opaque containers may be used in lieu of shoeboxes.

3. You may wish to attach some costs to each seismic search and/or drilling operation. Have the groups work as different petroleum companies and challenge each to find the oil quickly and cost effectively.

ACTIVITIES:

PART A: TAKING CORE SAMPLES

I. EXPLORING IN SMALL GROUPS

In this activity, students will construct stratigraphic models of likely and unlikely drilling sites, use drinking straws to take core samples, and then evaluate samples to determine whether the site would be a good candidate for development. Instruct your students to do the following:

- Plan two strata models—one which illustrates conditions conducive to the formation of a petroleum reservoir and another that would be unlikely to contain a reservoir.
- Use the materials provided by your teacher to build the strata models that you planned.
- Once your models are complete, push the drinking straw through each model from the top to the bottom. Remove the straw, which will now be filled with a sample of the model materials. Label each sample. Then, investigate the materials collected in the straw. Can you tell from the sample which model would be the most likely drilling site?
- Your teacher will collect the core samples and redistribute them randomly. Analyze the new samples and identify which represents a likely or unlikely drilling site.

II. DEVELOPING IN A LARGE GROUP

As a large group, have the students share and evaluate their findings. Refer back to the original group to debate, confirm, reject, or modify the second group's findings.

PART B: MAKING CORE SAMPLES

I. EXPLORING IN SMALL GROUPS

In this activity, students will create core samples in test tubes. Instruct your students to do the following:

1. Plan two strata models—one which illustrates conditions conducive to the formation of a petroleum reservoir and another that would be unlikely to contain a reservoir. Then, imagine what a core sample from each type of rock would look like.
2. Construct your models in test tubes using the materials provided by your teacher. Use the tamping tool to pack the sediments close together. Mark your sample for identification and record which samples represent likely and unlikely drilling sites.
3. Your teacher will collect the core samples and redistribute them randomly. Analyze the new samples and identify which represent likely or unlikely drilling sites.

II. DEVELOPING IN A LARGE GROUP

Have the students share and evaluate their findings. Refer back to the original group to debate, confirm, reject, or modify the findings of the second group.

PART C: SOUND SEARCH

I. EXPLORING IN SMALL GROUPS

Instruct your students to do the following:

- Use the funnel to fill a water balloon with cooking oil. Seal the balloon.
- Label the sides of the shoe box north, south, east, and west. Using the sand and igneous rock, carefully bury the balloon in the box. Use the ruler to record the orientation of the balloon in the box before you completely bury it. Fill the box full of sand and tape the lid firmly in place. The lid should be in complete contact with the sand.
- Exchange models with another group. Then, develop a method to find the location of the oil balloon (without removing the lid of the box). Write down your idea.
- Carry out your idea and record the orientation of the oil deposit. If your idea did not involve tapping on the container, try this method now and see if it works as well as your idea. Once you are confident that you have found the oil, record the orientation of the oil deposit and mark your drilling site.
- After obtaining permission from your teacher, begin drilling at the location you selected. Penetrate the box lid and tap down through the sand. Record how close you were to the oil.

II. DEVELOPING IN A LARGE GROUP

Have the students share their observations. Use the following questions to guide class discussion:

1. How can core sampling and seismic testing be used to find oil deposits?
2. What method did you choose for locating the oil? How did it compare to the methods chosen by other groups?
3. What special circumstances might make one method more useful than another?
4. How did your tests compare to actual oil prospecting operations?

BACKGROUND INFORMATION:

Once petroleum geologists have investigated the surface features of a potential site to determine whether an oil deposit exists below the surface, scientists turn to two important techniques to locate the deposit: core sampling and seismic surveys. Such procedures may cost anywhere from $10,000 to $50,000 per mile, which is still a lot less than drilling an exploration well.

To perform a seismic survey, scientists generate energy pulses or vibrations at the surface. Engineers can use several techniques to create the pulses. One method is to detonate dynamite in a shot-hole. Another method involves large, heavy trucks known as vibroseis trucks. Special rigs cause the trucks to vibrate at a controlled frequency, which delivers energy waves that travel through the subsurface. In offshore locations, vibrations are created by concussive releases of air. However they are generated, the pulses travel through subsurface rock layers, and when they encounter rock of a different density, some of the energy is reflected back to the surface. Geophones planted by the engineers receive the reflected pulses and relay them to a seismic group recorder (SGR). The SGR records the signals and provides data to computers, which process data into a graphic seismic profile or seismic line to obtain a picture of the subsurface rock strata.

Scientists can also learn a lot about subsurface composition by collecting core samples. Using special equipment, scientists drill into the ground and extract material, which they can examine themselves or submit to labs for testing. After analyzing all of the information collected, scientists can decide whether drilling an exploratory well is economically feasible.

PRACTICAL APPLICATIONS:

An understanding of petroleum exploration processes may help students to understand some of the implications of using fossil fuels for energy sources. These activities also help the students apply information gathered from previous investigations.

NOTES:

Putting oil into balloons and working with other materials in these activities may become messy. Be prepared with clean-up supplies.

ADAPTED FROM:

Lord, J. & Braaten, G. (1991). *Teaching about energy*, (Part 2). [The energy '90s teacher's resource book]. Santa Monica, CA: Enterprise for Education.

DEVELOPMENT QUESTIONS:

1. What variables determine whether you will find an oil deposit at a given site?
2. What is core sampling and how is it used to locate oil deposits?
3. How reliable do you think core sampling and seismic testing are?

APPLICATION QUESTIONS:

1. How is using sound to locate oil deposits similar to the ways sound is used to map the ocean bottom or by animals to navigate? Name some other ways that sound is used to locate objects.
2. In what other ways might core sampling be useful?
3. How would you use core sampling and seismic testing to find oil deposits offshore?

ASSESSMENT:

1. Save some of the student-produced core samples and have other students evaluate them.
2. Have the students describe the steps they would go through to find oil for an oil company.

EXTENSIONS:

1. Obtain portions of real core samples and real seismic lines from oil or petroleum exploration companies to share with the class.
2. Invite guest speakers from the petroleum industry to speak to your class.

MATERIALS LIST
ENVIRONMENT AND FUELING AROUND

Item	Activity	Amount for Class of 30
NONEXPENDABLE SUPPLIES:		
Balance	1	8
Bathroom scale	7	8
Beaker, 100 ml	1, 4, 12	8
Beakers, 250 ml	10, 11	24
Beaker, 1000 ml	3	16
Car, rolling, toy	8	8
Double boiler or substitute	4	1
Dropper, medicine	1, 4, 12	40
Eye protection	3	30
Flask, small	4	16
Funnel, glass, short-stemmed	3, 11, 13	16
Glass beads or BB's	10	800 mL
Graduated cylinder, 10 mL	1	8
Graduated cylinder, 100 ml	10	8
Graduated cylinder, 250 ml	11	8
Gravel	10	800 ml
Gravel sample	11	8
Hand lens	10, 11	8
Hot plate	3	1
Hydraulic jack	9	8
Jar with lid, clear	12	8
Laboratory thermometer	2	8
Lamp, 75-watt or larger (optional)	3	8
Lens, hand	1	8
Marbles or bearings	10	800 mL
Marker	4	8
Marker	12	8
Mass, 1-kg	8	8
Meterstick	6, 7, 8	16
Mortar and pestle	4	8
Oven mitts or substitute	3	1 pair
Paper clip, small	3	16
Petri dish	1, 3, 11	32
Ramp	8	8
Ring stand with ring	6	8
Rock sample, igneous	13	8
Rubber stopper, 2-hole, medium	6	8
Ruler	13	8
Samples of coarse sandstone, fine sandstone,		

MATERIALS LIST
ENVIRONMENT AND *FUELING AROUND* (CONT.)

Item	Activity Number	Amount for Class of 30
limestone, and shale	10, 11	8
Sand, sample	11	8
Sandstone, sample, approx. 4 cm diameter	12	8
Scissors	3	8 pairs
Screwdriver or knife	12, 13	8
Silt	10	800 mL
Silt, sample	11	8
Spoon, plastic or substitute	3	32
Spring balance	9	8
Spring balance, 20-newton	8	8
Stethoscope (optional)	13	8
Stirring rod, glass	1	8
Stopwatch	8, 11	8
Test tube	1, 3, 13	40
Test tube clamp	4	8
Test tube rack	1, 4	8
Test tube, Pyrex (optional)	4	112
Textbooks, any	8	40 or more
Timing device	3	8
Tweezers or clothespin	3	8
Watch, with second hand	7	8
Well plate, reaction plate, or reaction strip	1, 4	8
Wide-mouth jar or beaker	3	16
EXPENDABLE SUPPLIES:		
Algae culture	1	350 mL
Baking soda	3	8 tsp.
Balloon	13	8
Banana peel	2	8 pieces
Barley seedling, 5-day old	4	120
Benedict's solution	4	640 mL
Bentonite or other coagulant	1	80 mg
Beverage bottle, plastic, 2-liter	2	32
Black paper or foil, 5 cm x 2 cm approx.	3	16
Bottles, clear plastic, 2-liter	5	8
Calcium carbonate	5	24 g
Calcium chloride solution (5%)	1	80 mL
Calcium or magnesium sulfate	5	24 g

MATERIALS LIST
ENVIRONMENT AND *FUELING AROUND* (CONT.)

Item	Activity Number	Amount for Class of 30
Cheese cloth, 30 cm x 20 cm approx.	4	8 pieces
Chlorine tester	1	160 mL
Cooking oil	11, 13	1,000 ml
Cups, paper	4	16
Detergent, liquid	1	160 mL
Filter paper	1	16 or more
Elodea, sprigs, 6-8 cm approx.	3	310
Foam, impermeable, 2" x 2" x 1" approx.	11	8
Foam, permeable, 2"x 2" x 1" approx.	11	8
Funnel	1, 2	8
Graph paper	1	30 sheets
Hardness indicator solution	1	800 mL
Hypochlorite solution (5%) or liquid bleach	1	240 mL
Iodine solution, dilute	3	8 dropper bottles
Iron indicator solution	1	1,200 mL
Isopropyl alcohol, 70%	3	1,000 mL
Masking tape	6, 8, 13	6 or more rolls
Marker, small	1	30
Multi-vitamin tablet	5	8
Newspaper, 20 cm x 25 cm, finely shredded	5	8
Plaster	13	8 – 10 lbs
Potassium phosphate solution (5%)	1	160 mL
Potted plant (like geraniums)	3	2 – 4
Rod (for tamping)	5	8
Sand	12, 13	2,000 mL or more
Sand, fine	3	2 or more tsp.
Sandwich bag, plastic	2	8
Shoe box with lid	13	8
Soil	5	15 liters
Specially-prepared leaf (see Teacher Prep #2)	3	8 – 12
Starch solution, 0.25%	4	250 mL
Straw, drinking, clear	13	8
String, 100 cm	6	8 pieces
Table salt	1	40 g
Tape, masking	1	3 rolls
Toothpick, wooden	1	168
Variegated coleus (optional)	3	2 – 4
Vegetable oil	12	1,000 ml or more
Water, distilled	1, 4	4,100 mL
Water, iron-supplemented	1	80 mL

MATERIALS LIST
ENVIRONMENT AND FUELING AROUND (CONT.)

Item	Activity Number	Amount for Class of 30
Water sample, bottled spring water	1	400 mL
Water sample, distilled water	1	400 mL
Water sample, mineral water	1	400 mL
Water sample, tap water	1	400 mL
Water test sample	1	1,600 mL
Water, specially-prepared (see Teacher Prep #7)	3	10,000 mL
Yeast, dried	4	2 tsp.

KEY

Activity #	Activity title
1	Nor Any Drop to Drink
2	Rot Around the Clock
3	Light and Dark
4	Where Does Carbon Come From?
5	Pond Bottom
6	What Happens to the Energy of a Pendulum?
7	Who Did More Work?
8	Down the Hill
9	Lifting Heavy Objects
10	Hol(e)y Rocks
11	Ive Got Connections
12	Migrating Fluids
13	Where, Oh Where Can It Be?

California SS&C

Offshore Oil Drilling

CALIFORNIA SS&C
INTRODUCTION

Welcome to the Offshore Oil Drilling Curriculum Module. This module is the product of a collaborative endeavor between the American Petroleum Institute (API) and the California Scope, Sequence, and Coordination (SS&C) Project, with fiscal management and oversight provided by the California Science Teachers' Association. We are particularly pleased with this module, as it represents the best of coordinated science in an instructional unit that brings together biology, physics, chemistry, and the geological sciences through interesting, hands-on, and technologically rich investigations.

The API was interested in exploring coordinated science as a vehicle for presenting the more complex, modern aspects of energy education that might not be readily available in most high school curricula. This module was written in a large part because the California SS&C Project saw this as an opportunity to create a module that demonstrated the type of coherent, in-depth, instructional unit described in the California Science Framework. The module was developed by SS&C teachers and API engineers and scientists who have extensive technological expertise in offshore mining resources.

This module is meant to be used serially. Each chapter addresses a different aspect of oil exploration. The final chapter component, "Regulatory Meeting on Offshore Oil Development," can be used as an assessment activity to tie everything together (an example of "embedded assessment"). We see this module as fitting directly into a coordinated or integrated science program, not only because students are interested in the political and ecological implications of the economic resources off shore of California, but also because petroleum chemistry is a big part of our everyday experience, influencing the way we travel, dress, and heat our homes, to name a few of its applications.

As part of the development process, we field-tested this coordinated science unit in a number of SS&C schools in California. It is now ready for use in a "convertable" fashion so that it can be used in both coordinated and integrated courses throughout the United States. We hope, in large measure, that this project gives you the opportunity to recognize the particular science that goes into industrial fields and the knowledge needed for use in petroleum industry careers. These characteristics can stimulate the interest of students to pursue careers in the petroleum industry.

Petroleum in Our Daily Lives

Students investigate the role petroleum plays in their daily lives. They will examine how petroleum affects their quality of life and discuss how the choices they make affect the need for oil. They will also learn how oil impacts the environment by studying its possible effects on a marine ecosystem.

TIME NEEDED: Five days

UNIT DESCRIPTION:

Oil exploration and extraction affects the marine environment—and, by extension, the marine environment greatly affects the discovery and extraction of oil. Now that we have explored and developed most of the land areas in the United States, scientists believe that untapped oil reserves remain to be found offshore, beneath the ocean floor. New technological developments have made deep water offshore drilling feasible, but the marine envrionment also complicates oil drilling and extraction. At the same time, we must also study how offshore oil drilling will affect the delicate marine ecosystem.

In this section, students will first explore the role that petroleum plays in their daily lives. In the first activity, **Life without Oil?**, students will identify and classify a variety of materials based on their current knowledge of petroleum-based products. In the next activity, **The Quality of Life**, students will discover how petroleum-based products are used in their homes, and will consider whether they could live without petroleum. After a brief overview explaining what oil is and the procedures used to explore and extract it, students will investigate the different environments where oil can be found by way of a class game or a computer game (The Oil Game, available for Apple IIe computers). In the activity, **Life in the Marine Environment**, students will form a food web of a marine biome and explore how it might change if the petroleum industry were introduced.

Throughout the unit, students should be encouraged to:

1. discuss their views and form hypotheses that they will continually challenge as they proceed through the unit;
2. examine the geology of the ocean by creating black box models;
3. practice map-making by exploring models built by other students in the ocean bottom extension challenge;
4. investigate the impact of petroleum on the standard of living.

MATERIALS:

PART A: **Life without Oil?** (Each group should have more than ten items from each category)

Examples of petroleum-based

products (suggestions from Student Information Sheet #2, pictures of medicines, rubbing alcohol, various toiletries and cosmetics)

Examples of nonpetroleum-based products (cotton wool silk, wood, glass, uninked paper, organically grown produce or any other food that has not been sprayed with insecticides)

PART B: The Quality of Life

100 m white string
100 m colored string
tape
index cards (one per student)
scissors
marking pens (optional)

PART C: Life in the Marine Environment

Index cards labeled with the following organisms: phytoplankton, octopus larvae, large and small fish (any type), and carnivorous predatory fish and mammals, such as sharks and orca.

TEACHER PRELAB PREPARATIONS: FOR PART A:

Objectives:

Students will classify items into appropriate categories based on prior knowledge and reclassify the same items into appropriate categories using new information. You should encourage students to become aware of the role petroleum plays in their daily lives.

Set-up:

1. Make a transparency of Student Information Sheet #1 to use during class discussions.
2. Place samples in either a cafeteria-style tub or on trays, separated for each lab group. The samples need not be the same for each group. In fact, more variety frequently leads to better large group discussions. Hint: Check the teacher's lounge, storage cabinets, and cafeteria for items.

Procedure for Session I:

1. Copy and distribute the Student Materials, reserving the Student Information Sheets for the second session.
2. Divide the students into groups of four to six students.
3. Students will divide the materials into petroleum-based and nonpetroleum-based products.
4. Once all the students have finished making their lists, have each group present its list of petroleum-based products. Be prepared for an interesting class discussion, as students will probably disagree with some of the classifications offered by their peers. Do not discourage disagreement, but do encourage students to support their claims with evidence. Do not reveal which classfications are right or wrong; let the students wonder.
5. Record on the board or a piece of butcher paper a cumulative list of petroleum-based products for the whole class.
6. Collect each group's individual lists.

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7. Assign the Activity Challenge. Remind the students that they should try not to wear petroleum-based products to school for the next session.

Procedure for Session II:

1. Have students regroup.
2. Return the lists that you collected in Session I. Hand out the Student Information Sheets.
3. Allow students to work through the activity and answer the discussion questions.
4. When the students have completed the activity, have each group introduce its top "petroleum-less" dresser. Ask the students to point out any innovative items that their group discovered at home. Be sure to evaluate how well you came to school "petroleum-less."
5. Use the discussion questions to lead a class discussion. Answers will vary depending upon how successfully the students handled the challenges.

FOR PART B:

Objectives:

Students will create an energy web to illustrate how fossil fuels impact their standard of living and quality of life. You should help the students to ascertain how much we rely on petroleum products and to notice that petroleum, fossil fuels, and other natural resources have an enormous effect on the energy web.

Set-up:

1. Fill out one index card to read "PETROLEUM."

Procedure:

1. Copy and distribute the Student Materials.
2. Do not rush this activity. For step 5, each individual should connect to the others one at a time. This allows the entire class to see what the connections are and to point out other connections. Patience with the activity will give your students the time they need to appreciate the complexity of an energy web.
3. In step 7, have the students disconnect one at time. Help the class to see what happens as portions of the web collapse.
4. Assign the discussion questions as homework, use them to guide class discussion, or let the students discuss the questions in their groups or with partners.

FOR PART C:

Objectives:

Using what they learned in Part B about food webs and energy transfer in ecosystems, students will create a simulated marine food pyramid.

Set-up:

1. Label index cards with the organisms listed on the Student Information Sheet for Part C. Each organism represents a different trophic level. Trophic level 1 contains primary producers, such as phytoplankton. Trophic level 2 contains primary consumers, such as octopus larvae. Fish can also be members of trophic level 2, though many are secondary consumers, and thus members of trophic level

3. Trophic level 4 contains top predators, such as sharks and orkas.

2. Place enough cards in the box that when the class draws cards they will form a standard trophic level—that is, a large biomass of primary producers with a smaller biomass of consumers and top predators. The top predators should have the fewest number of cards. You will probably need additional index cards when the students begin simulating environmental changes.

Procedure:

1. Copy and distribute the Student Materials.
2. Before beginning the activity, students should read the Student Information Sheet.
3. Ask the students to arrange themselves in a pyramid according to what they think the predator-prey relationships might be.
4. Continue to work through the activity, giving the students time to perform the environmental change simulations. Students will explore the effects of overhunting top predators, overharvesting of primary consumer fish, and offshore oil drilling. They should also answer the questions on the Student Information Sheet.
5. Assign the Activity Challenge.

Petroleum in Our Daily Lives

Part A: Life without Oil?

OBJECTIVES:

To classify items into appropriate categories based on prior knowledge and to reclassify the same items into appropriate categories using the new information that you will acquire in this activity.

INSTRUCTIONS:

Session I:

1. Work in groups of four to six.
2. Choose someone to be the recorder for your group and someone to be the chairperson.
3. The recorder will divide a piece of notebook paper into two sections-one labeled "Petroleum-based" and the other labeled "Non-Petroleum-based."
4. While the recorder prepares the notebook paper, have the chairperson get the materials from the teacher.
5. The recorder lists the materials used by your group at the top of the notebook paper.
6. As a group, decide which materials should be listed under "Petroleum-based" and which should be listed under "Non-Petroleum-based." Have the recorder write down the group's decisions. If there is disagreement talk about it. Everything must be categorized.
7. The chairperson should note any important aspects of the discussion, especially the disagreements, and be prepared to make a brief report to the class.
8. As a group, be prepared to explain why you classified your materials the way you did. Support your claims with evidence.

Session II:

1. Work in the same group as you did in the last session.
2. Have the chairperson get your materials from the last session and a copy of Student Information Sheets #1 and #2 for each member. Read over both sheets as a group.
3. Review your list from the last session and compare it with Student Information Sheet #2.
4. Have your recorder make a new list of materials. Reclassify your materials based on what you learned from reading the Student Information Sheets.
5. After your group has reclassified the materials, take a look at the lists that you generated for Activity Challenge #1. Decide whether you need to change some of the classifications. Make any changes that seem appropriate.

6. Examine how well each person in your group dressed today without petroleum-based products. Select the "best-dressed" person to introduce to the class.

DISCUSSION QUESTIONS

1. How successfully were members of your group able to dress without wearing any petroleum-based products?
2. Are there any items that you forgot to consider? For example, does your underwear have an elastic waistband? Is your zipper made of metal? Did you use mousse or gel in your hair this morning?
3. If you had to remove ALL the clothing items made from petroleum-based products, what would you have left?
4. What types of things could you substitute for the removed items? How would you feel about wearing them?
5. How well would you be able to change your lifestyle to avoid using petroleum-based products?
6. How well did your teacher come dressed "petroleum-less" today?

ACTIVITY CHALLENGE

Based on what you experienced during Session I, complete the following challenge at home. Bring your results to use during Session II.

1. Make a list of the petroleum-based and nonpetroleum-based products found in your home. Get an adult to help you look through any cabinets or in the garage. Be prepared to point out at least five items from each category to your classmates. Hint: To keep things interesting, try to find items that you didn't look at during Session I. Challenge yourself!
2. Try your best to come to school tomorrow without wearing any petroleum. Think carefullly about this. Your teacher will also attempt this challenge.

LIFE WITHOUT OIL
STUDENT INFORMATION SHEET #1

We use petroleum in many forms during the course of a day—the clothes we wear, the sports and entertainment we pursue, the way we get to work or school, even our morning bathroom rituals, rely on petroleum-based products. Plastics, for example, can be found everywhere from video games to lunch trays. By far the largest amount of petroleum consumed in the United States is in the form of gasoline. Every year, American vehicles consume 100 billion gallons of gasoline and 16 billion gallons of diesel fuel. Aircraft, factories, and homes also rely on petroleum products for power and energy. All in all, petroleum is used to produce 3,000 different types of commonly used products.

Because petroleum has so many important applications, people have been finding ways to extract petroleum from the environment for thousands of years. Noah reportedly coated the Ark with an asphalt-like petroleum called bitumen. The Greeks used oil to set fire to attacking fleets.The Romans used "Sicilian oil" to light their temples. The Chumash tribe in what is now California used asphalt from seeps to caulk their canoes, and other Native Americans used whale oil for light and heat. Oil seeps were used to grease wagon wheels as Americans moved west, and the first American car was successfully operated by fuel in 1893. While the Chinese first drilled for crude and natural gas in 374 A.D., it took fifteen centuries for the "Age of Petroleum" to begin in the West, when Edwin Drake "struck oil" in 1859.

When the internal combustion engine was invented in 1885, the Industrial Revolution put new demands and strain on the petroleum industry. Even the first rocket-fueled engines used by NASA were powered by kerosene and hydrogen peroxide. If we are to maintain our current lifestyles and fulfill our current levels of production and demand, the amount of oil and gas produced each year must somehow be replaced, as we are quickly expending the fuel available in natural oil reserves.

VOCABULARY

Asphalt: Heavy black residue left after removing the tar tailings in distillation of petroleum. Asphalt used in roofing and for roads.

Bottled Gas: Propane, butane, and pentane, used in cook stoves and for lighting and heating.

Distillation: The process of separating crude oil into various liquids by heating.

Gasoline: Colorless liquid hydrocarbon obtained during distillation. Used primarily as a motor fuel, gasoline represents the largest percent of petroleum used in the United States.

Mineral Oil: Very fine, pure petroleum oil used in laxatives.

LIFE WITHOUT OIL
STUDENT INFORMATION SHEET #1 (CONT.)

Nylon: A group of synthetic plastics. In fiber form, nylon is used in clothing, carpet, surgical sutures, brushes, tennis strings, and fishing line. In film form, nylon can be used as wrapping and packaging material.

Paint: "Painter's" naphtha is used as a thinner in paints, varnishes, and lacquers.

Paraffin wax: First distillate taken from petroleum after the cracking process. Paraffin wax is used for waterproofing and coatings for milk cartons, shower curtains, candles, and crayons.

Petrochemicals: Organic chemicals obtained from petroleum. Examples are isopropyl alcohol, propylene, benzene, chemical fertilizers, plastics, synthetic rubber, and solvents.

Petroleum jelly: Substances obtained in the distillation process, which are used in ointments and lubricants.

Synthetic rubber: Product similar to natural rubber made from hydrocarbons and containing long isoprene. Synthetic rubber is used to make tires, coatings, and a number of other products.

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LIFE WITHOUT OIL
STUDENT INFORMATION SHEET #2

SAMPLE PETROCHEMICAL PRODUCTS

gas
enamel
vacuum bottles
panty hose
oil filters
model cars
tires
lipstick
tennis racquets
roller blade wheels
life jackets
plastic bags
shower curtains
golf balls
fishing rods
soft contact lenses
hand lotion
salad bowls
cameras
artificial limbs
bandages
beach balls
ball-point pens
tape recorders
dashboards
slacks
petroleum jelly
antihistamines
LP records
cold cream
antifreeze
balloons
saccharin
candles
paper
asphalt
butane

marking pens
antiseptics
purses
shag rugs
cassettes
floor wax
toothpaste
combs
house paint
eyeglasses
TV cabinets
loudspeakers
credit cards
detergents
glue
dice
shampoo
awnings
anesthetics
heart valves
dentures
boats
nail polish
caulking
putty
yarn
perfume
cortisone
solvents
umbrellas
luggage
mineral oil
soaps
grease
ink
milk cartons
paint thinner

telephone
transparent tape
deodorant
rubbing alcohol
video tapes
sports bottles
dish washing liquid
ice cube trays
drinking cups
guitar strings
buckets
movie film
aspirin
sun glasses
plastic wood
trash bags
shaving cream
safety glass
artificial turf
parachutes
mops
inflatable rafts
tool boxes
vitamin capsules
skis
insecticides
food preservatives
dyes
vaporizers
synthetic rubber
footballs
artificial leather
insulation
polyester
nylon
propane
film

Americans consume petroleum products at a rate of three and a half gallons of oil and more than 250 cubic feet of natural gas a day per person.

Petroleum in Our Daily Lives

Part B: The Quality of Life

OBJECTIVES:

You have probably heard the terms "standard of living" and "quality of life." What do these terms mean to you? What exactly is a high standard of living, and what does it have to do with quality of life? In this activity, you will investigate these questions by creating an energy web with the other members of your class.

BIG IDEAS: The earth's resources are limited; living organisms interact with the environment.

INSTRUCTIONS:

1. Make a list of the products and services that you associate with a high standard of living.
2. Taking turns with the other students in your class, contribute one service or product from your lists (avoiding duplication). Your teacher will write the contributions on the board. After your contribution has been noted, write it down on an index card.
3. When everyone has contributed, your teacher will collect the cards and redistribute them randomly. After you receive your card, tape it on as you would a name tag.
4. One student will have a tag reading "petroleum." This student will remain outside the group during the first part of this activity.
5. Stand in a circle with your classmates holding a length of white string. Your task is to connect yourself to all the other students (products) that you need to obtain the product or service that you represent. For example, a car needs metal, gas, rubber, etc. Do not rush. You may help each other. When you have finished, take a look at what you have formed.
6. Now have the "petroleum" student stand in the center of the circle. Using lengths of colored string, each student (product) that requires petroleum for energy connects to the petroleum.
7. To simulate the effects of a fossil fuel shortage, remove all colored strings. This also means you will need to remove the white strings between people who no longer have enough energy to sustain their product or service. These students should leave the circle.
8. When you have finished, answer the discussion questions on your own.

DISCUSSION QUESTIONS:

1. What was formed when all the students were linked together?
2. What happened when the fossil fuel shortage occurred?

3. What happened to the circle after the fossil fuel shortage caused students to leave the circle? Why did this happen?
4. What hardship would a "simple standard of living" impose on people?
5. What would be the advantages of a simpler way of living?
6. Describe a high standard of living that would not require fossil fuel for energy.

Petroleum in Our Daily Lives

Part C: Life in the Marine Environment

OBJECTIVES:

To create energy pyramids that will illustrate life in a marine environment. You will also investigate how offshore oil drilling could affect this environment.

INSTRUCTIONS:

1. Collect the Student Information Sheet for this activity from your teacher. Read it before beginning this activity.
2. Obtain an index card with the name of an organism on it.
3. Determine what trophic level your organism belongs to.
4. Together with your classmates, arrange yourself in a pyramid according to the trophic level you belong to.
5. Answer the activity questions listed on the Student Information Sheet.
6. Perform the following environmental change simulations on your pyramid: overhunting of top predators, overharvesting of primary consumer fish, and offshore oil drilling. What are some of the effects of these changes on the marine environment? Create a new pyramid to illustrate the consequences of these situations.

DISCUSSION QUESTIONS:

1. What organism did you draw from the box?
2. What trophic level does your organism belong to?
3. What is the niche of your organism?
4. What predators consume your organism?
5. What does your organism prey on?
6. Draw a diagram of the food pyramid created by the class. Label each level of the pyramid with the organisms that represented that level.

ACTIVITY CHALLENGE:

Thinking back on the food web, consider the effects of introducing an offshore oil platform into this delicate ecosystem. Then answer the following questions:

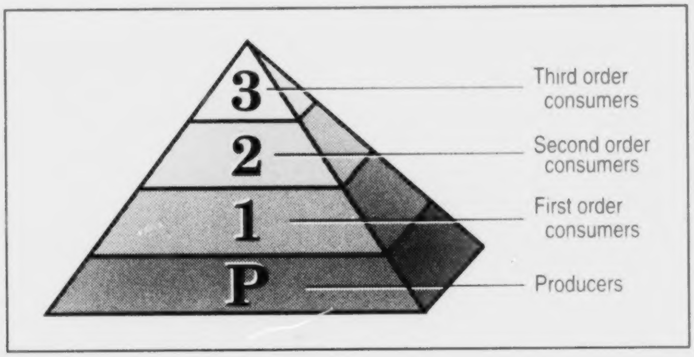
1. How might an oil platform itself harm or benefit the marine environment?
2. How might the exploration and extraction of oil affect the environment?
3. How might spilled crude oil affect the upper level of the ocean? (Hint: Does oil float or sink in saltwater?) How would this affect the marine food web? Outline an example.
4. In addition to the impact on the food web, in what other ways could spilled crude oil affect life in the ocean?

LIFE IN THE MARINE ENVIRONMENT
STUDENT INFORMATION SHEET

All organisms need energy in order to survive. This energy begins with the sun and flows from one organism to the next. We call this flow of energy a food chain. One organism eats another organism, and then the feeder is eaten by another organism. When death occurs at any level of the food chain, a decomposer continues the energy flow by breaking up and consuming the remains of the dead organism.

The small plant-like organisms, such as algae, and other small organisms called diatoms form the foundation of the marine food chain. All sea animals depend upon diatoms for food, either directly or indirectly. Diatoms are also produce approximately 75 percent of the oxygen in the air.

The ocean is home to a wide variety of plant and animal life. Some of the organisms found in the marine food chain are phytoplankton (microscopic plant-like organisms), zooplankton (microscopic animal-like organisms), bacteria, algae, crustaceans (barnacles, crabs, shrimp), coelenterates (jellyfish, coral), tunicates, mollusks (clams, oysters, scallops), fish of all sizes (including sharks), marine mammals (whales, seals, sea otters), sea birds, humans, and shore-based mammals, such as bear, that feed in intertidal areas. These organisms depend on each other for food and trace their source of energy back to the sun.



A food pyramid illustrating the trophic levels of a food chain.

ACTIVITY QUESTIONS:

1. Why do you suppose we call the flow of energy through an ecosystem a food chain?
2. Using the list of organisms described above, identify which are:
   - producers
   - primary consumers

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THE MARINE ENVIRONMENT
STUDENT INFORMATION SHEET (CONT.)

- secondary consumers
- decomposers

3. What is the common source of energy for all these organisms?
4. Which organisms seem to be eaten the most?
5. What organism did you draw from the box?
6. What trophic level does your organism belong to?
7. What is the niche for your organism?
8. What predators consume your organism?
9. Draw a diagram of the food pyramid created by the class.

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Oil Exploration

Students will share with each other their current understanding of oil and gas exploration activities. They will create a laboratory model to observe how oil deposits form. They will also learn how scientists map the underground to search for new sources of oil.

TIME NEEDED: Five days

UNIT DESCRIPTION:

By participating in three related activities, students gain an appreciation for the size and scope of oil exploration and production activities.

The first activity, **What Do You Know about Oil Production?**, surveys the students' prior knowledge of global oil exploration, importation, and consumption through a question and answer game. Students roam the room with a particular question taped to their backs, collecting answers to the question from other students as they go. At the conclusion of the game, students report the answers that they collected, and try to guess what question they wore.

The second and third activities simulate actual processes used in oil exploration. In the second activity, **How Do Oil Deposits Form?**, students learn about permeability and density by exploring geological oil migration and entrapment. Students create a source, reservoir, and trap/seal model using cups, gravel, clay, water, and oil. They observe oil rising through a simulated reservoir column as a function of oil/water density contrast, and note how oil accumulates beneath an impermeable layer.

In the final activity, **Mapping the Underground**, students learn how scientists use the travel times of longitudinal waves to locate potential offshore drill sites. Using Slinkys, students visualize sound energy as a traveling wave. The students then learn how waves are propagated, once again using Slinkys to determine distance by measuring the two-way travel time of reflected waves.

MATERIALS:

PART A: What Do You Know about Oil Production?

signs containing the survey questions
pencils
paper

PART B: How Do Oil Deposits Form?

1 16 oz package modeling clay
10 lb bag coarse white gravel, such as aquarium gravel
300 mL vegetable oil
Clear 10 oz plastic cups
600 mL salt water colored with blue food coloring (make a

saturated solution using 16 tablespoons of salt per liter of water)
blue colored pencils (optional)

PART C: Mapping the Underground
metal Slinkys
stopwatches
reflectors (use thin textbooks, or make reflectors using 8 inch squares of 3/4 inch thick plywood)

TEACHER PRELAB PREPARATIONS:
FOR PART A:

Objectives:

Students will investigate their preconceptions about oil exploration and production through a question and answer game. Your job will be to help the students reach conclusions and to introduce new concepts to them in class discussion.

Set-up:

1. Copy and cut out the question signs that follow the materials for this unit. You may want to copy the signs onto cardstock or similar firm paper so that you can reuse them for each class. Label groups of the same question with numbers or colored dots to help the students consolidate responses during the oral report phase.
2. You should limit the number of questions to allow two or three students to have the same question. This will ensure that all the students answer each question, which will provide a more representative data set for analysis and discussion. Choose from the questions given, supplementing your own if necessary.

Procedure:

1. Copy and distribute the Student Materials.
2. Have the students divide into pairs. Each student will tape a sign onto their partner's back. Students should not be able to see the question and should not ask other students what the question is. Tell the students to write down at least ten answers to their question.
3. When the students have completed their survey, ask them to present the responses that they received and to guess what their questions were. Put the range of answers on the board for discussion.
4. Lead a discussion based on the survey results. Provide correct answers to the questions if they were not obtained during the survey. Encourage the students to examine how their attitudes toward oil reflect those of the larger U.S. community. Should the U.S. be concerned about its oil consumption? Where does the oil that we use come from?

Discussion Questions:

The following questions have been enlarged for photocopying at the end of the teacher materials for this unit. Here are the questions and answers to help you guide discussion:

1. **Which country produces more oil and gas than any other?**
   The former Soviet Union produces

more oil and gas than any other country. The following ranking shows the top five oil-producing nations, in terms of millions of barrels of oil per day (MMBOPD). One barrel equals 42 gallons.

Former Soviet Union:10
Saudi Arabia: 6 (has a capacity to produce 10)
U.S.: 7
Iran: 3
Iraq: 3

The middle eastern countries of Saudi Arabia, Kuwait, Iran, and Iraq together contain approximately 75 percent of the world's known oil reserves.

2. **For every 100 wells drilled, how many find oil and gas?**
   Approximately 10 percent of all wildcat exploration wells make a commercial discovery. Many wells actually encounter oil and gas, but not in profitable production quantities.

3. **From the time oil or gas is discovered, how long does it take to reach the consumer?**
   The time ranges from one month to twenty years. Onshore fields that are close to production facilities can produce oil very quickly. Several factors can delay the drilling and extraction process. For an offshore field, water depth and distance from shore can pose difficult engineering problems. Currently the deepest oil production is in 2,000 ft. of water from a Shell field in the Gulf of Mexico. Unstable foreign political situations, environmental concerns, and unfavorable economic conditions can also delay field development.

4. **How much does a barrel (42 gallons) of oil cost?**
   In January 1994, the cost was $14.85 per barrel. The business section of most newspapers will carry quotes for specific types of crude oils.

5. **Which country uses more oil or gas than any other.**
   The U.S., which on a per-day basis, uses 16 MMBOPD, or 25 percent of total world consumption.

6. **How many barrels of oil are used in the world every day?**
   Total world consumption of oil runs at about 65 MMBOPD. At 1994 prices, we could produce 991 billion barrels of oil from known reserves.

7. **What percentage of U.S. oil needs comes from imported oil?**
   The U.S. currently imports about half of the oil it uses.

8. **How much does it cost to drill an offshore exploration oil or gas well?**
   One frontier wildcat exploration well can cost anywhere from $5-$25 million to drill, depending upon water depth, environmental conditions, and engineering complexity.

9. **How many barrels of oil can a super tanker hold?**
   A super tanker holds more than

one million barrels of oil (42,000,000 gallons).

10. **How many barrels of oil were spilled into Prince William Sound, Alaska by the Exxon Valdez?**
    258,000 barrels (10,836,000 gallons).

11. **How much oil is accidentally spilled into the ocean each year?**
    Approximately 6 MMBO (252 billion gallons).

12. **How much oil enters the ocean each year from natural oil seeps on the sea floor?**
    Approximately 4.5 MMBO (189 billion gallons).

Answering these questions should also allow you to raise several issues during class discussion.

- The U.S. government has long been concerned about our country's dependency on foreign oil, particulary the oil supplied by politically unstable or hostile nations.
- Keep in mind that oil and gas are nonrenewable resources that we will someday deplete. Researchers estimate that existing oil reserves only contain 30 years more oil. While we will certainly find more reserves, these new reserves will probably be more difficult to produce, which will increase oil prices.
- Oil production raises many environmental concerns. Spills affect marine life, pollutants in the groundwater harm humans and animals, and refineries also release toxins into the atmosphere. But while oil companies need to change some of their policies to address these issues, you should remind the students that society's demand for oil creates many of these problems. To help the students understand this concept, consider assigning a homework assignment asking the students to write a one-page opinion on who they feel is responsible for the environmental problems associated with petroleum production. Make these assignments the subject of a discussion the following day.

FOR PART B:

Objectives:

In this lesson, students will study the conditions necessary for the formation, migration, and entrapment of hydrocarbons. Students will make a layered model of sediments, simulating the source of hydrocarbons, the porous and permeable rock that stores hydrocarbons, and the impermeable rock that seals and traps the hydrocarbons. Guided discovery allows students to observe many different properties of oil.

Set-up:

1. Designate an area where the students can store their cups overnight.

Procedure for Session I:

1. Copy and distribute the Student Materials.
2. Divide the students into pairs and have them work through the lab.

Emphasize the need for a good seal between the clay disc and the cup.

3. Remind the students to answer the discussion questions.

Procedure for Session II:

1. Redistribute the cups and have the students finish answering the lab questions.
2. Ask for volunteers to draw their diagrams on the board. Discuss the changes occurred in the cups. You may need to review with students what density, porosity, and permeability are.
3. After discussion, go over the Student Information Sheet and have the students complete the Activity Challenge in class or as a homework assignment.

Discussion:

During the discussion, describe what causes the formation, migration, and entrapment of oil, and relate the actual processes to the student models. You will need to focus your discussion on some specific topics, which are outlined below.

Source rock. Ask the students how they think oil is formed. Many may know that buried plants form coal deposits. A similar process occurs in oceans. As plants and animals die, they sink to the bottom of the sea and decay. Sometimes, though, there is not enough oxygen available for the organic material to decay; this condition is called anoxia. When this happens, the organic material is buried by mud and silt, and, over millions of years, the pressure generated by the accummulating layers of sediment raises the temperature and "cooks" the organic material. As the material heats up, it is converted into hydrocarbons, such as oil and gas, in a process called thermal maturation. Plant material generally turns into gas, while animals, particularly certain types of plankton, tend to form oil. The sedimentary layer containing the organic material is called source rock because it is the source of the hydrocarbons.

To help the students understand how the layers or sand, silt, and mud cover the organic material, draw a diagram on the board or overhead. Emphasize that it takes millions of years for the layered sediments to create the pressure necessary to heat the organic material enough to break it into hydrocarbons. The conditions are quite precise. If the temperatures are not sustained long enough, the maturation process will not occur. In addition, if the organic material cooks for too long, it turns into graphite.

Oil formation, then, is a rare occurence and geologists rely on this rarity when they analyze an area's potential for producing oil or gas. Source rock can tell scientists a lot about the conditions in which it was formed. Finding mature rock rich in organic material can prompt geologists to investigate the area further.

Reservoir Rock. Ask the students how they think oil exists underground, and how oil companies locate it (the latter question will be dealt with in the next unit). Explain that oil exists in the spares, or pores, between rock fragments, in the same way that groundwater is stored in an aquifer, or reservoir. When the permeability is high enough, water in an aquifer can be drawn to the surface by drilling a well into the reservoir. Oil works in the same way, and rocks that have adequate porosity and permeability for oil or gas to flow through them are called reservoir rocks.

Trap and Seal. Abundant, high-quality reservoir rocks cannot help a petroleum company if the hydrocarbons have nowhere to accumulate. Reservoir rocks containing oil also contain water. Since oil is less dense than water it buoyantly rises through the permeable reservoir until it meets a permeability barrier, such as a layer of shale or mudstone. Oil accumulates in this space, which is called a trap. While many different types of traps exist, they all possess a barrier or seal that prevents further hydrocarbon migration.

Rare Occurrence. The increasingly high cost of oil and gas attests to its relative rarity. All the conditions must be perfect for hydrocarbons to accumulate properly. And even then, the amount of oil accumulated may not be enough for a petroleum company to drill and develop the reserve.

FOR PART C:

Objectives:

Students will learn how geologists determine the subsurface structure of sedimentary rocks. Scientists use reflected sound waves to map various rock layers. These maps can help them determine the location of potential hydrocarbon traps. Your students will use Slinkys to visualize sound energy as a traveling wave. They will then propagate the waves and ascertain the distance by measuring the two-way travel time of reflected waves.

Set-up:

1. Familiarize yourself with the calculations that the students will perform in this lab. Travel times obtained from the Slinky tests will be converted into distance via $d=vt/2$. Students will plot the various distances to produce a profile that simulates an anticlinal form.
2. Since your class will perform these experiments in groups using their own Slinkys, it is critical that all the Slinkys have approximately the same amount of tension. Check the tension by attaching a spring scale to one end of the Slinky. Stretch the Slinky until the scale registers 300 g. You will achieve the best results if the Slinky is 12 feet long at 300 g of tension.
3. To achieve the anticlinal form when the students plot the results, you will need to place the reflectors a predetermined distance from the end of Slinky. Try this part of the experiment beforehand to determine the best distance to use. Distances less than five feet make it difficult to time the two-way travel accurately.

Procedure:

1. Copy and distribute the Student Materials. Remind the students to handle the Slinkys carefully, as the coils are easily damaged.
2. Some students may have trouble with the math involved in this experiment. If so, go over the example problem given on the Student Information Sheet.

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3. After the students have completed the lab, talk about what the procedure taught them. Geoscientists use waves to determine distance and image subsurface rock structure. Reflection profiles generated by sound waves play a key role in helping scientists identify the location of potential hydrocarbon traps, which can tell them the best place to drill a well.
4. Complete the Activity Challenge in class or assign it for homework.

Discussion:

Ask the class what the following have in common: clapping hands, the school bell, and thunder. Clap your hands and ask the students what just happened. Explain that the force of your hands coming together caused the air molecules around them to vibrate. As the energy of this vibration was transferred to other air molecules further and further away, each vibrating at the same frequency as the one before, a wave was produced. Eventually, this propogating wave reached their ears and caused their eardrums to vibrate. We recognize the vibrations as a sound.

The students may have seen an example of wave propogation on television. In Westerns, trackers often put their ears to the ground to hear the hoofbeats of distant horses. The trackers can hear the vibrations of hoofbeats transmitted through the ground sooner than they could hear the noise through the air. Additional examples of sound transmission are submarine detection, ultrasound images of babies in the womb, and bats tracking insects in the air at night. Briefly discuss these examples to familiarize students with how reflected sound can be used to image objects hidden from our view. You might even consider bringing in a "fish finder" echo-sounding device to profile a transect across the room.

Using an overhead of the geological cross-section on the Student Information Sheet or a diagram on the board, point out the various sedimentary layers. Ask how this profile might have been made. Explain that reflected sound waves can help geologists to image various layers of rock.

Reflection seismology is the most important tool available for determining subsurface structure. Geologists generate sound waves with an explosion or other intense vibration at the surface. The wave travels through the sedimentary column. At an interface between two different sedimentary layers, some of the waves are reflected back to the surface. Special instruments at the surface record the arrival times of sound waves as they return. Scientists can calculate the distance from the surface to the rock layer boundary with the following formula: distance = velocity x time ÷ 2. We need the divisor to convert the distance from a two-way measure to the simple distance from the surface to the rock. Computers process the data, and profile the sedimentary layers. These profiles are then used by geologists to identify potential hydrocarbon traps and prospective drill sites.

Questions

Which country produces more oil and gas than any other?

For every 100 wells drilled, how many find oil or gas?

From the time oil or gas is discovered, how long does it take to reach the consumer?

How much does a barrel of oil (42 gallons) cost?

Which country uses more oil or gas than any other?

How many barrels of oil are used in the world every day?

What percentage of U.S. oil needs come from imported oil?

How much does it cost to drill an offshore exploration oil or gas well?

How many barrels of oil can a super tanker hold?

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How much oil was spilled into Prince William Sound, Alaska by the Exxon Valdez?

How much oil is accidentally spilled into the ocean each year?

How much oil enters the ocean from natural oil seeps on the sea floor?

Oil Exploration

Part A: What Do You Know about Oil Production?

OBJECTIVES:

To explore your ideas about oil exploration and global dependency upon oil. During a question and answer game, you will accumulate information about your own and your classmates' prior knowledge about oil production and use.

BIG IDEAS: The earth's resources are limited.

INSTRUCTIONS:

1. Divide into pairs and collect two question cards from your teacher. Do not look at the cards! Have your partner tape a question card on your back. Then return the favor. Do not tell each other what the questions are!
2. Roam around the room, letting your classmates see your question. Begin collecting answers (you will need to write down ten answers to your question).
3. Read the questions posted on your classmates' back and offer them your answer.
4. When everyone has received ten answers, review the answers you received and guess what question is taped to your back. You will present your findings during class discussion.

Oil Exploration

Part B: How Do Oil Deposits Form?

OBJECTIVES:

To discover how hydrocarbons form, migrate, and become trapped beneath the earth's surface. In this lab, you will create a layered model of sediments, simulating a hydrocarbon source, the porous and permeable rock that stores the hydrocarbons, and the impermeable rock that traps the hydrocarbons.

BIG IDEAS: Matter has observable, physical properties that can be measured. The earth's resources are limited.

INSTRUCTIONS:

Session I:

1. Divide into pairs for this activity.
2. Label the cup with your initials.
3. For this experiment to work, it is crucial that you maintain a good seal between the clay disc and the cup. Keep this in mind as you work.
4. Press the clay into a disc about 5.5 mm thick and 6.5 cm in diameter. Set this aside.
5. Pour 100 mL of gravel into the cup and shake it gently to distribute it evenly along the bottom. Add the oil to the cup, observing how it fills the pore spaces between the gravel.
6. Pour 50 mL of gravel into the cup, and add the colored water.
7. Place the clay disc on top of the gravel. Form a seal around the outer edge of the disc by pressing it against the sides of the cup. Make sure that you get a good, tight seal.
8. Pour the remaining gravel on top of the clay layer, and add the colored water to the top of the gravel.
9. Draw a picture of the cup and its contents. Wait ten minutes and draw another picture, taking care to note any changes within the cup. Clearly label your diagrams. Place your cup in the area designated by your instructor. Then answer the first part of the first discussion question.

Session II:

1. Pick up your cup from your teacher and draw a picture of the cup's contents. Finish answering the discussion questions.

DISCUSSION QUESTIONS:

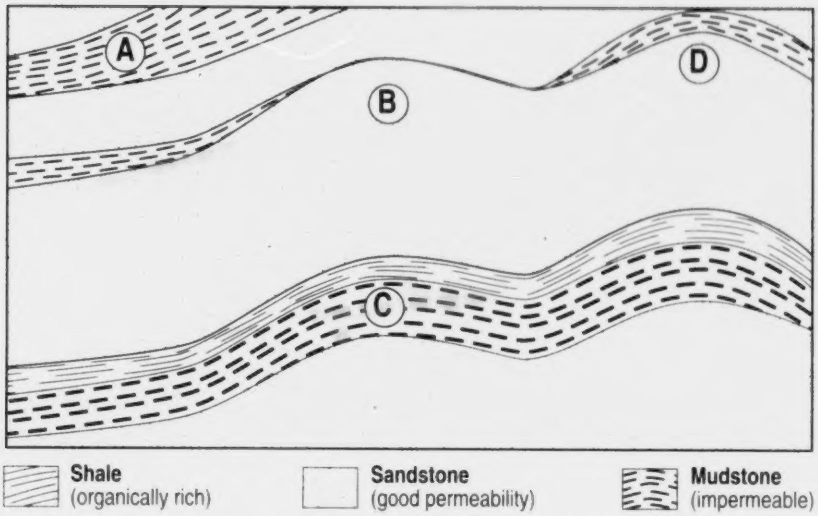
Answer the following questions as you complete each part of the activity:

1. Finish these statements with complete sentences that describe the changes that you observed in the contents of the cup.
   - 10 minutes after the water was added. . .
   - 24 hours after adding the water. . .
2. Why did these changes occur?
3. What purpose did the clay layer serve?

ACTIVITY CHALLENGE

Note: Read the Student Information Sheet before answering these questions.

1. What is meant by the "richness" of certain types of rocks? Why are rich rocks important to petroleum companies searching for oil fields?
2. Describe how plankton is converted into hydrocarbons.
3. Why is it important for petroleum geologists to know that oil is less dense than water?
4. The following diagram shows layers of rocks beneath the surface of the earth. Assming that geologists have identified high quality source rocks and reservoir rocks in this area, which of the possible locations A, B, C, or D do you think might contain an accumulation of oil or gas? Explain your answer.



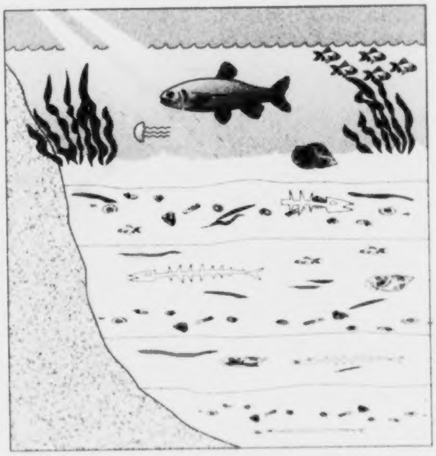
Layers of rocks beneath the surface of the earth.

HOW DO OIL DEPOSITS FORM?
STUDENT INFORMATION SHEET

How are hydrocarbons formed? Where do we find them? And why do they only occur in certain places? Earth scientists have been searching for the answers to these questions since commercial oil drilling began in the early 1900s. People found the first oil fields by looking for pools of oil that collected where oil had seeped from below the surface. As more and more people began to demand cheap oil and gas, petroleum companies began hiring geologists to locate other sources for oil. The results found by these 100 years of laboratory research and exploratory drilling are the product of a story that began millions of years ago.

How Does Oil Form?

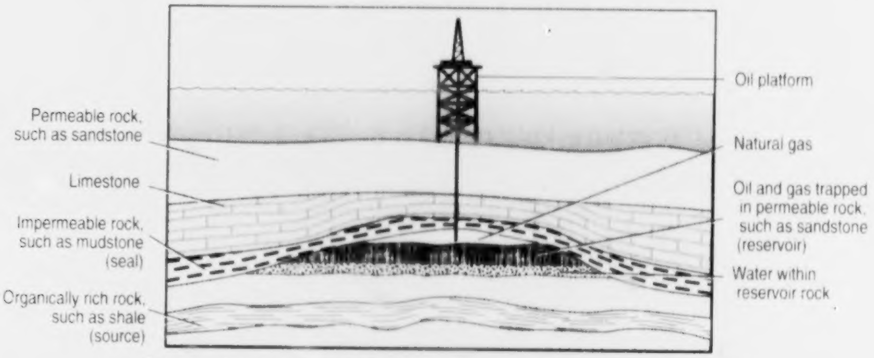
The oil and natural gas taken from the earth's crust today originated as tiny plants and animals that lived in the sea millions of years ago. As the plants and animals died, their bodies sank to the bottom of the sea. When oxygen was available, their bodies decayed. But occasionally, oxygen is not available at the bottom of the sea. We call these conditions anoxic (without oxygen). When the bodies encountered anoxic conditions, they failed to decay and gradually became covered with layers of mud and silt. Over millions of years, the layers of sediment generate an enormous amount of pressure, which raises the temperature in the space containing the organic material. The plant and animal bodies cook, and, under the right conditions, are converted into the hydrocarbons known to us as oil and gas. The layer of sedimentary rocks that contain oil and gas are known as source rocks.



A layered model of sediments with sand, silt, and mud covering organic material.

Where Is Oil Stored?

Contrary to what you may believe, oil does not pool beneath the surface in underground lakes. Once the hydrocarbons have formed in source rocks, they migrate through the different layers of sedimentary rocks until they reach a barrier. The oil and gas migrates through tiny pore spaces between the grains of rock. When a material allows


Permeable rock, such as sandstone
Limestone
Impermeable rock, such as mudstone (seal)
Organically rich rock, such as shale (source)
Oil platform
Natural gas
Oil and gas trapped in permeable rock, such as sandstone (reservoir)
Water within reservoir rock

Oil and gas trapped within layers of sedimentary rock.

fluids to pass through it, it is permeable. For example, when you water your houseplants, the water flows through the soil because the soil is permeable. Rocks that are porous and permeable enough to allow oil or gas to flow through them are called reservoir rocks. These rocks hold the oil like a giant sponge holds water.

Why Are Reservoir Rocks the Best Place to Find Oil?

Reservoir rocks containing oil also contain water. Since oil is less dense than water, it buoyantly rises through the permeable reservoir until it meets a permeability barrier, such as a layer of shale or mudstone. The oil accumulates in this barrier, called a trap. There are many different kinds of traps, but each one has an effective barrier or seal to keep the hydrocarbons from migrating. Why are these locations the best place to find oil? Imagine trying to quench your thirst by catching rain drops on your tongue one by one. A more efficient way would simply be to pour yourself a glass of water to drink. The same is true about extracting oil from the ground. To justify the high cost of drilling oil wells, petroleum companies have to be sure that there will be large quantities of oil trapped in one place. Thus, they look for reservoir rocks, which indicate the presence of oil.

The Need for Proof

Before a company drills a well, scientists study the area thoroughly to determine the chances of finding oil there. Petroleum geologists study samples of rock collected from the surface, testing to see how much organic matter they contain (a measurement known as richness). Richer rocks typically produce more oil and gas than leaner rock. Scientists also test the permeablity of reservoir rocks. The more permeable the rock, the higher the rate of oil flow, which means that the well will produce more oil.

Once the geologists have determined that a location has a good chance of producing a high quantity of oil, they begin looking for trapped gas and oil. This is usually the most expensive and time-consuming part of the pre-drill investigation, and take years to complete. You will learn how geologists look for traps in the next activity.

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Oil Exploration

Part C: Mapping the Underground

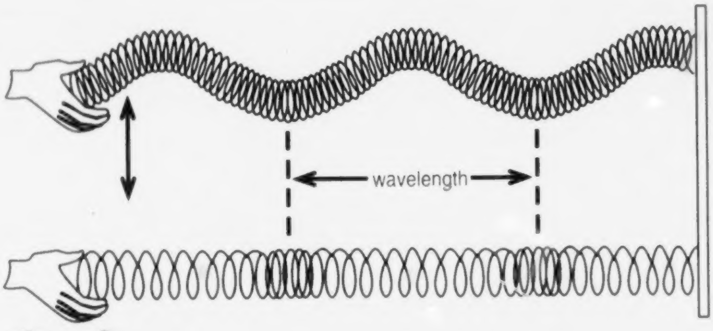
OBJECTIVES:

In this activity, you will learn how geologists map the subsurface to locate potential oil drill locations. Using Slinkys to visualize sound waves, you will determine distances by measuring the two-way travel time of a longitudinal wave.

BIG IDEAS: Sound is a vibration in matter.

INSTRUCTIONS:

1. Obtain the materials from your instructor.
2. Generate a transverse wave in the Slinky by shaking the end of the Slinky side to side. Then create a longitudinal wave by shaking the Slinky in and out. Sound waves are longitudinal waves. Draw pictures of these waves.
3. Attach a spring scale to one end of the Slinky. Stretch the Slinky until the scale registers 300 g. Using the stopwatch, determine long it takes for a longitudinal wave to travel the length of the slinky. Do this several times until you get answers that are within 0.2 seconds of each other. Compare your times to those obtained by other groups. Why might the times differ?
4. Place a reflector between coils of the Slinky at the position indicated by your instructor and according to



Both waves transfer energy from left to right. When the end of the Slinky is shaken up and down (top), a transverse wave is produced. When it is shaken in and out, a longitudinal wave is produced.

the diagram below. Determine how long it takes for a longitudinal wave to travel from one end of the Slinky to the reflector and back again. This is called the two-way travel time. Record the times in a column labeled "Time" on a sheet of paper.

5. Obtain two-way travel times from the other groups and record these values in the "Time" column.
6. Calculate the distance from one end of each spring to the reflectors using the following formula.

   distance=(velocity x time) ÷ 2

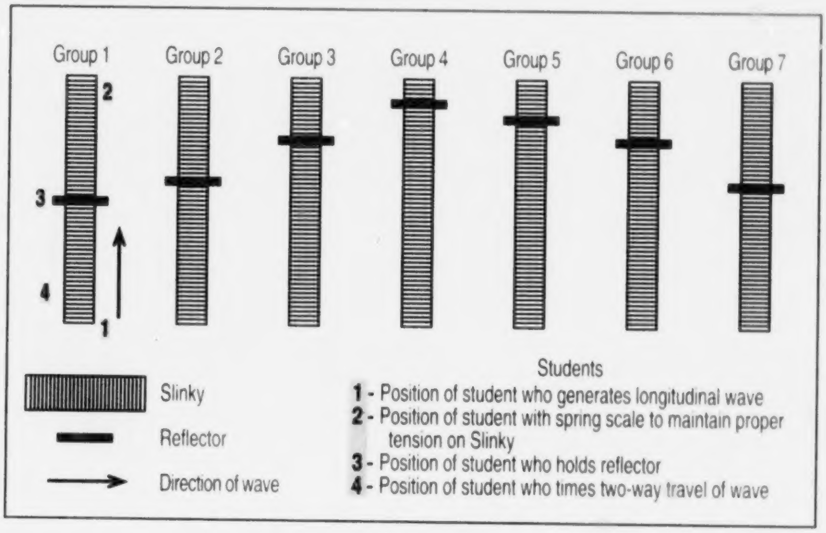
   Record these values in a column labeled "Distance" in your table. Assume the velocity is 4.0 m/s.

Ex: velocity=4.0 m/s
  time= 1.8 s
  distance=(4.0m/s x 1.8 s) ÷ 2
  distance=3.6 m

7. Plot the distance values for each group on a sheet of graph paper. Connect the marks with a line. Be sure to properly label your graph.

ACTIVITY CHALLENGE:

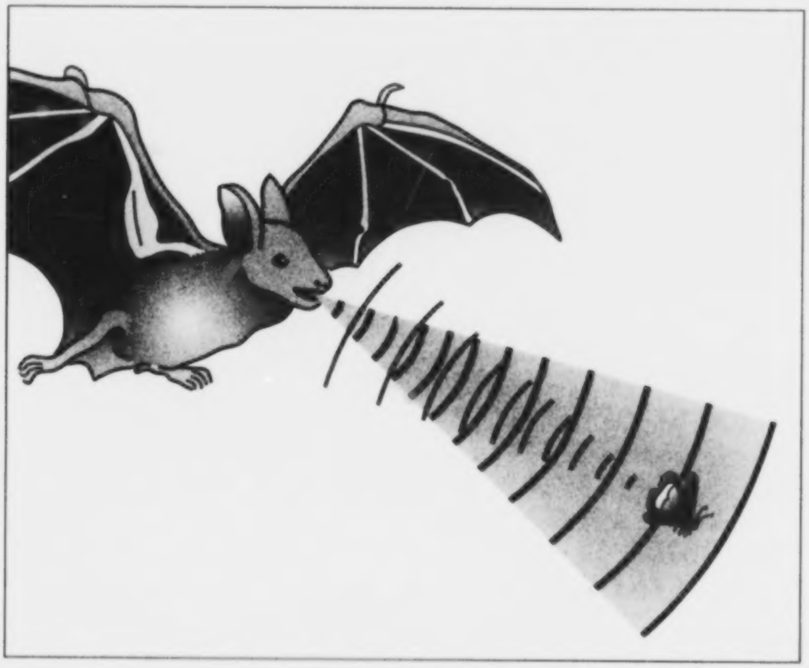
1. Using your knowledge of sound waves, describe how the following procedures work:
   - submarine detection by a ship on the surface of the water;
   - images of a fetus in a woman's womb.
2. You've just returned from your grandmother's house. A friend asks how far away she lives. You reply that you don't know, but that you can figure it out. Your mother drove an average of 50 mph to get to your grandmother's house and it took four hours to drive there and back. How far away does your grandmother live from you? Show all your calculations.
3. Someone once suggested that oil


Group 1
Group 2
Group 3
Group 4
Group 5
Group 6
Group 7
2
3
4
1
Slinky
Reflector
Direction of wave
Students
1 - Position of student who generates longitudinal wave
2 - Position of student with spring scale to maintain proper tension on Slinky
3 - Position of student who holds reflector
4 - Position of student who times two-way travel of wave

companies could save lots of money by firing all their geoscientists and forgetting about using data analysis to determine drill sites. They suggested that wells be drilled according to a grid pattern. Each well would be 100 miles from another well. What do you think about this idea? Explain your answer.

MAPPING THE UNDERGROUND
STUDENT INFORMATION SHEET

Most sound waves we hear are transmitted through the air. But sound also travels through solids and liquids. An ear placed to the ground can hear the hoofbeats of distant horses before they can be heard in air. Because ground is denser than air, sound travels faster through it.



Reflected sound waves are like reflected echoes. Bats use reflected sound waves to navigate while flying. The high-pitched squeaking sounds that bats make bounce off of objects, helping them "see" what is in front of them, even in total darkness.

Geologists studying the subsurface also use reflected sound waves to help image layers of sedimentary rocks that they think might contain hydrocarbons. Controlled explosions are often used to generate sound energy pulses, which travel through the ground and reflect off different layers of rock below the surface. These reflected waves can be detected at the surface by special instruments. Computers then sort out all the different sound wave arrivals and produce a profile of the subsurface. Scientists can then can determine how deep the rock layers are using a simple calculation:

distance = velocity x time ÷ 2

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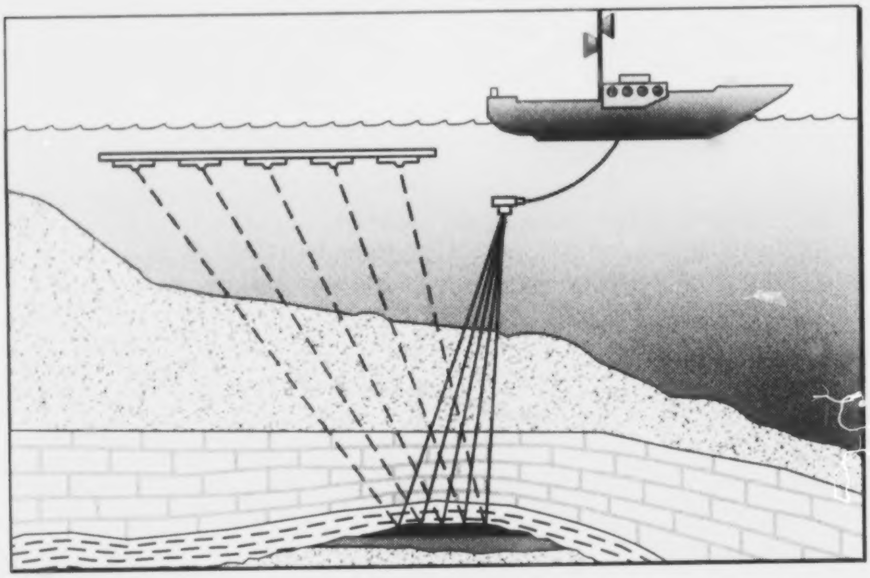
MAPPING THE UNDERGROUND
STUDENT INFORMATION SHEET

Knowing how deep a rock layer is tells scientists how productive the well will be. Engineers doing the drilling need to know the exact place to drill the well and how deep to drill in order to find hydrocarbons. Identifying the right location for a deep well depends on an accurate analysis of sound wave data.



To help determine where an exploratory well should be located, underwater sound waves are sent from a ship to reflect off rock layers situated underground. The relected sound waves are detected by special instruments at the surface.

Oil Extraction

Through several related activities, students will learn about the processes, technologies, and people involved in offshore oil drilling and production.

TIME NEEDED: Five days

UNIT DESCRIPTION:

Present technology allows us to extract energy resources from many parts of the earth. During this unit, students will investigate the materials and techniques used by oil experts to remove oil from offshore reservoirs.

The first activity, **What Do You Know about Oil Extraction?**, introduces students to the concept of offshore oil drilling. Students will offer their ideas about how oil is extracted from deep sea reservoirs in a one-page report.

During the second activity, **Getting Oil out of the Ground**, students will watch a video and read information sheets to learn how oil derricks are built. They will then work as planner/economists to ascertain whether their companies can afford to build a derrick at a paricular location

The final activity, **Who Does What?**, allows students to model the duties of different oil industry executives. Students will choose whether they want to serve as environmental/civil engineers, drilling engineers, logging/reservoir engineers, or extraction mud engineers. Through a series of laboratory activities, students will learn different aspects of the oil production process. Finally, the students will present what they have learned about oil technology to their company. Company members will share their knowledge to determine the feasibility of an oil drilling site, and the entire company will then report their findings to the rest of the class.

MATERIALS:

PART A: What Do You Know about Oil Extraction?
overhead of ocean surface, ocean floor, and oil reservoir

PART B: Getting Oil out of the Ground
Shell video
graph paper

PART C: Who Does What?

1. **Environmental/Civil Engineer (for each group)**
   iron filings
   250 mL glass beaker
   9 petri dishes
   5 iron nails
   1 galvanized nail
   1 painted nail
   water
   sand

    - salt
    - 1 beaker containing vegetable oil

2. Drilling Engineer I (for each group)
    - 1-inch copper tubing (1 ft long)
    - 1-inch galvanized steel tubing (cut two pieces, one 1 ft long, the other 6 ft long)

3. Drilling Engineer II (for each group)
    - wooden board
    - peg board
    - test tube
    - rubber stopper
    - turn glass tube
    - glass beads
    - rubber tubing
    - Bunsen burner
    - test tube clamp
    - pin
    - circular scale
    - 1/4-inch copper tubing (2 ft long)
    - petri dish lid
    - water
    - matches
    - clothespin

4. Logging/Reservoir Engineer I
    - 100 mL glass beaker
    - cooking oil
    - water
    - granite rocks (1-3 cm)
    - long-necked glass funnel
    - glass tube (50 cm)

5. Logging/Reservoir Engineer II
    - stethoscope
    - 1 ft wooden dowel
    - balloon
    - cooking oil
    - sand
    - granite rock (1-3 cm)
    - diatomaceous soil
    - 4 plastic tubs, with lids (10 cm x 25 cm x 20 cm)

6. Extraction/Mud Engineer
    - balance
    - graduated cylinder (25 mL or 50 mL)
    - samples of unknown liquids (labeled A, B, and C)

TEACHER PRELAB PREPARATIONS: FOR PART A:

Objectives:

Students will offer ideas about how they think offshore oil drilling works.

Procedure:

1. There are no student materials for Part A.
2. Using an overhead projector, draw the ocean surface, the ocean floor, and an oil reservoir. Have the students complete the picture by drawing how the oil is removed.
3. Have the students explain their drawing in a one-page report. Remind them to think about issues of extraction and safety.

FOR PART B:

Objectives:

Students will watch a video about building an oil derrick, and will also learn about this process by reading a Student Information Sheet. They will then explore what they have learned by acting as planner/economists, and, through a series of calculations, will determine the economic implications of building an oil rig.

Procedure:

1. Copy and distribute the Student Materials.
2. Show the Shell video. Explain to students that the video is narrated by a boy whose father is working on the derrick project. Afterwards, discuss how the derrick was set.
3. Tell the students to read over Student Information Sheets #1 and #2. Divide the students into two or three groups to work out the problems and complete the graph. Remind the students to keep copies of their calculations and graphs for themselves, so that they can contribute to their company's presentation to the rest of the class.
4. Have the students present their results to the class. Extension: Using the business section of your local newspaper, have the students determine whether, at today's oil prices, their company would make a profit building the platform and producing oil at this particular site.
5. Go over the answers to the Problems.

Problems (Answers)

1. The total value of the oil is $600,000,000. The company can therefore make $100,000,000 from the reservoir. You should recommend that the company produce the oil.
2. The total value of the oil is $880,000,000. The company can therefore make $380,000,000 from the reservoir. You should recommend that the company produce the oil.
3. A war in the Middle East could interrupt the oil supply, which would raise prices. Better car fuel efficiency would decrease oil consumption, thereby reducing demand, increasing supply, and lowering prices.

FOR PART C:

Objectives:

Working in groups of five, students will form their own oil companies and choose a profession within that company. Members of the same profession will perform a series of laboratory experiments and report on the experience to other members of the company. The goal is for all the students to learn about the different types of people and technologies that are a part of the oil industry.

Set-up:

1. Copy and distribute the Student Materials.
2. Divide the students into groups of four. Tell them to come up with a name and logo for their company. Each member should also choose a profession based on the descriptions offered in the Student Information Sheets.
3. In the Environmental/Civil Engineer experiment, the iron filings should start rusting within several hours. The water in the beaker slowly rises as the oxygen is used up during the oxidation process (rusting). Because, oxidation is a slow reaction, students will need to leave the

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experiment in the room for a few days. The equation for the reaction is

$$4 Fe + 3O_2 \longrightarrow 2Fe_2O_3 + heat$$

The iron loses electrons, becoming Fe+3 and the oxygen gains electrons, becoming O-3. The reaction is exothermic, which explains why heat is produced. As far as the results the students should obtain, Nail #1 should not rust, Nail #2 should rust, Nail #3 should have more rust, Nail #4 should have more rust at the bend, Nail #5 should have less rust (the oil acts as a coating to prevent oxygen from reaction with metal), Nail #6 should have less rust or no rust (the paint coats and protects the nail), and Nail #7 should not rust.

4. In the Extraction/Mud Engineer experiment, you will need to supply at least three different unknowns of different densities. The densities of some liquids that you can use in this experiment follow:

   cottonseed oil: 0.917-0.918 g/mL
   glycerin: 1.26 g/mL
   mineral oil: 0.8275-0.886 g/mL
   water: 0.997 g/mL

   Make these values available to students after they have completed the experiment so that they can find out what their unknowns were.

4. You may wish to have each student record the results of the experiments they witness in research journals. Regardless, you should have them all report back to their companies and work with their fellow workers to complete the discussion questions. When the experiments have finished, each company will present its results to the class. If time allows and you have the resources, consider providing overhead transparencies or video cassettes so that students can produce professional presentations.

For the various laboratory procedures, see the Student Instructions for each experiment.

Oil Extraction

Part B: Getting Oil Out of the Ground

OBJECTIVES:

In Part A of this unit, your instructor had you offer suggestions about how oil is extracted from the ground. During Part B, you will learn about the decisions involved in constructing an offshore derrick. Then, as a planner/economist for an oil firm, you will perform a set of calculations to determine whether your company will make a profit by building a platform and extracting oil from a given site.

INSTRUCTIONS:

1. Watch the video and read over the Student Information Sheets.
2. Your teacher will divide you into two or three groups of planner/economists. Using the information you have learned, perform the calculations to answer the questions below.

PROBLEMS:

1. Your company believes that there are 40,000,000 barrels of oil in the ground at a new location. It will cost you $500,000,000 to build a platform and produce the oil. The price of oil has just fallen to $15/barrel. **Questions**: What is the total value of the oil in the ground? How much money will your company make if it decides to build a platform and produce the oil? Can your company afford to produce this oil?
2. Elsewhere, your company discovers another 40,000,000 barrels of oil in a reservoir. The cost to build the platform and produce the oil is still $500,000,000. But now, the price of oil has increased to $22/barrel. **Questions**: What is the total value of the oil in the ground? How much will your company make if it decides to produce oil at this location? Can your company afford to produce this oil?
3. Graph the oil price ($/barrel) vs. company profit (in millions of $) for the problems above and for the example from the video. Use the graph to determine when the cost of oil/barrel will produce no profit for your company.
4. List some factors that might affect the price of oil. For each item that you list, write down whether you think it will increase or decrease the price of oil and explain your answer. For example, a cold winter would increase the demand for oil, reducing the oil supply and raising the price of oil.

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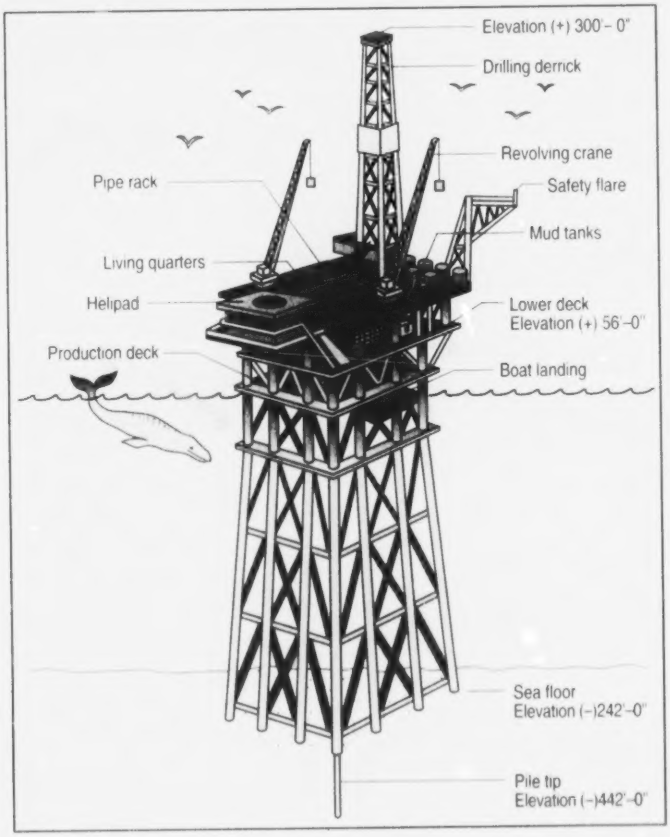
GETTING OIL OUT OF THE GROUND
STUDENT INFORMATION SHEET #1

BUILDING AN OFFSHORE DERRICK

Now that you have viewed the video, you can begin to appreciate the size of offshore drilling operations. Although accidents do occur, oil companies spend a lot of time and money to ensure the safety of their personnel and of the local marine environment. Oil companies use offshore oil drilling platforms to remove oil from ocean locations. The platform is attached to the sea floor with pylons, which hold the jacket legs in place. The jackets and braces hold the platform above the ocean surface and also store fresh water for the crew. Oil platforms have three principal layers. The lower layer, or spider deck, sits just above the surface of the sea and is used for oil well guides and boat docking. The second layer is used for ongoing oil production after the wells have been drilled. The upper unit is the main drilling deck. Let's examine the operations that occur here.


Elevation (+) 300'- 0"
Drilling derrick
Revolving crane
Pipe rack
Safety flare
Mud tanks
Living quarters
Helipad
Lower deck
Elevation (+) 56'-0"
Production deck
Boat landing
Sea floor
Elevation (-)242'-0"
Pile tip
Elevation (-)442'-0"

An offshore oil platform.

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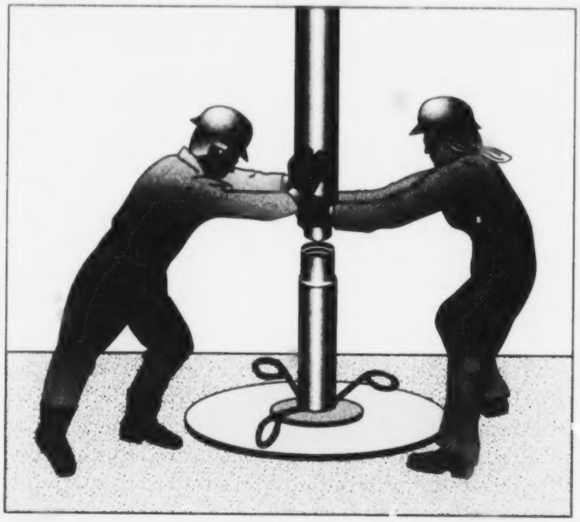
GETTING OIL OUT OF THE GROUND
STUDENT INFORMATION SHEET #1 (CONT.)

Drilling for Crude

The drilling operation starts at the base of the derrick, where the driller and roustabouts feed a steel pipe down the well hole. Mud engineers check that the drill bit stays cool, ensure that rock shavings are carried away from the drill bit, and keep the oil inside the hole to prevent blowout. They accomplish this by pumping mud down the center of the drill piping to the bit area. As the drill string moves further inside the hole, drillers control the revolutions of the top-drive motor and the pressure on the column of piping. Simultaneously, roustabouts connect three 30-foot sections of drill pipe into 90-foot stacks. They add these stacks to the drill string and send them down the hole.



Roughnecks in a drilling team work to connect new lengths of pipe. After the pipe is connected, it is lowered down into the well so that drilling can begin again.

Twenty-four hours a day the drill bit cuts through rock layers on its journey to the oil reservoir. Each drill bit exhausts itself after around 30 hours. Replacing the drill bit requires drillers to pull the entire string of pipe out of the hole. Drillers and roustabouts spend hours pulling and stacking the piping until the end of string is reached. The drill bit is then replaced and sent back down the hole. As the oil well gets deeper, progressively smaller bits are used. At the well head, drillers use a 17.5 inch-diameter drill bit. But at 775 feet below sea level, the drill bit is only 12.5 inches in diameter. Once the drillers hit the reservoir, they switch to a seven-inch bit. Engineers cement metal casings into place to protect the hole from cave-in. These metal casings also get smaller and smaller as the well gets deeper in order to make the hole stronger. Logging engineers monitor the stability and safety of the well and check underground substrates using electronic sensors similar to sonar. Logging engineers also work with the drilling engineers to decide where to drill additional wells.

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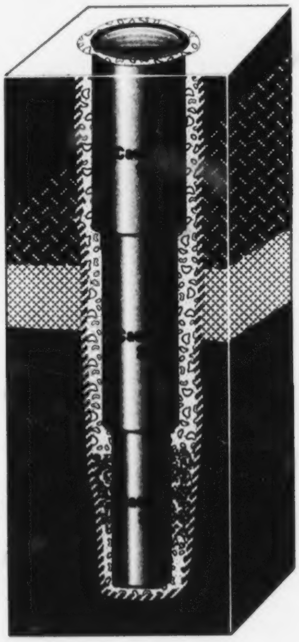
GETTING OIL OUT OF THE GROUND
STUDENT INFORMATION SHEET #1 (CONT.)

Once the drillers reach the oil deposit, reservoir engineers measure the amount of oil present. These engineers may ask the drillers to drill several exploratory holes to determine the extent of the trap. Often, reservoir engineers choose to drill wells horizontally so that the well travels through the deposit, thereby optimizing oil extraction. But even then, deposits typically yield only 30 percent of the oil they contain because the oil tends to cling to the surrounding soils.

Once the hole has been completely dug, engineers set explosive charges in the reservoir. The explosives perforate the pipe, allowing oil to seep in and to be pumped to the surface. The crane then moves the drilling derrick to a new location on the deck by sliding it along a ramp. Large metal sprockets keep it on the track and lock it into place. Then a new well is started and the process starts all over again. Eventually, one platform may have as many as thirty wells.



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BIOGRAPHY: PLANNER/ECONOMIST

Tom Burns started his career with an extensive education, receiving a B.S. and M.S. in Industrial Management from the Massachusetts Institute of Technology. After graduating, he worked for Caltex Oil Co., a subsidiary of Chevron Oil. He has been with Chevron ever since, moving up into different positions and taking on new responsibilities. Presently he is working in Chevron's corporate planning and analysis department, making major decisions on the company's international oil production as a planner/economist.

As an economist, Tom helps Chevron decide which tracts of oil-producing land to purchase and drill on. Because his decisions commit Chevron to multimillion-dollar investments and hundreds of jobs, Tom needs to see the big picture. He makes these decisions by working closely with several other Chevron employees. Geologists show him charts indicating how much oil a reservoir contains. Drilling engineers inform him about how difficult it will be to get oil out of the ground. And after several wells are drilled, Tom consults reservoir engineers to find out how much oil the well might yield using secondary methods.

Tom enjoys working as a planner/economist quite a bit because it allows him to use a variety of skills. His mathematical knowledge helps him compute the financial success of major drilling operations. He also takes advantage of his technical and business talents. In addition, he needs to have good speaking skills to present the information to his bosses when they make major policy decisions. And when one of Tom's superiors questions his figures, he uses his keen analytical ability to answer the inquiry.

Although Tom's job requires him to work in an office all week, he does find the time to travel and to enjoy the outdoors. While working at Chevron, he has lived in several locations in the United States and Europe and has been able to participate in many of his favorite activities, including running, skiing, biking, and windsurfing. All and all, Tom wouldn't trade his life with anyone.

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Oil Extraction

Part C: Who Does What?

OBJECTIVES:

Oil extraction involves many different people, all of whom offer their expertise to help extract oil from the ground efficiently and safely. In this activity, you will learn about the duties of these individuals by forming a mock oil company and taking on the role of an employee in the organization. After participating in research groups with others in your chosen profession, you will present your findings to your company and to the class.

INSTRUCTIONS:

1. Your instructor will divide you into groups of four. Read over the Student Information Sheets. Decide whether you want to be a planner/economist, an environmental/civil engineer, a drilling engineer, a logging/reservoir engineer, or an extraction mud engineer. Your group should also decide on a name and logo for your company.
2. Once you have decided on your occupation, you will be assigned to various workstations with other members of your class who have chosen the same profession that you have. Instructions for each of those activities are listed below. Record your results so that you can report them back to your company.
3. After completing the laboratory exercises, prepare a visual presentation for your company, and present this report to your group. Then work with your group to answer any company problems related to each exercise.

Specific instructions for the individual exercises follow.

ENVIRONMENTAL/CIVIL ENGINEER

In this activity, you and other experts in your field will determine which of two metals is the best one to use in building an offshore oil rig.

Part 1:

Examine the two pieces of iron metal and describe the differences between them. Try to figure out what might cause these differences. Then answer the following questions.

1. What causes the differences between the nails?
2. How do you think the reddest one got that way?
3. Which metal would you rather use to build your oil rig? Why?

Part 2:

1. Choose one of the other environmental/civil engineers to work with on this experiment.

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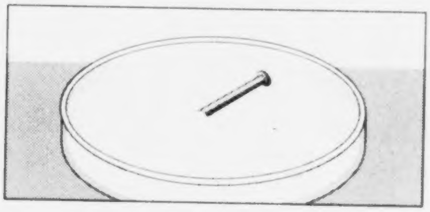
2. Moisten the inside of the beaker by filling it with water and then pouring the water out. Fill the beaker with iron filings. Shake the filings around until a few stick to the inside of the beaker. Remove the other filings. Turn the beaker upside down in a petri dish filled with water.
2. Repeat the experiment using salt water to moisten the jar.
3. Watch the beakers for a day or two and make careful notes about your observations.
4. Meanwhile, use sandpaper or emery cloth to clean the five iron nails until they are shiny.
5. Label the seven remaining petri dishes #l through #7.
6. Place dry sand into petri dish #1 and bury a nail about halfway in the sand, as in the diagram below.



Lab set-up for petri dish #3.

7. Place damp sand in dishes #2 through #7 and do the following:
   a. bury an iron nail in dish #2.
   b. mix one teaspoon of salt with the sand and bury an iron nail in dish #3.
   c. bend an iron nail and bury it in dish #4.
   d. dip an iron nail in oil and bury it in dish #5.
   e. bury a painted nail in dish #6.
   f. bury a galvanized nail in dish #7.
8. Leave the dishes overnight and record what happens to each nail.

Extension:

In this experiment, we saw that iron forms a reddish coating, called rust, under certain conditions. Rusting is a form of corrosion, similar to the type of corrosion that occurs when silver tarnishes, or gets dull and dark.

Millions of dollars are spent every year to keep iron and steel from rusting. Air, particularly air that is moist or salty, causes rusting to occur. Thus bridges, for example, are kept painted to keep them from rusting. Tin cans are really iron cans coated with tin to protect them from rust. Garbage cans are made from zinc-coated iron called galvanized iron. Iron can also be coated with copper or chromium.

Not all metal rusts like iron. Stainless steel, which is made by melting together iron, nickel, and chromium, does not rust.

Company Problem:

With the rest of your company, discuss the following problem and come up with possible solutions:

Your company is in charge of a huge oil rig. What types of preventive measures must your company use to prevent or decrease corrosion? Develop a six-month plan for dealing with the corrosion on your rig. How much will you need to spend to implement your plan?

DRILLING ENGINEER

In Part I, you and your fellow drilling

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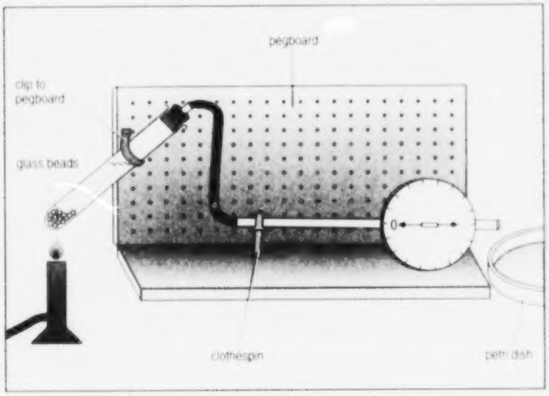
engineers will investigate how much different metals bend. Drilling engineers exploit this property of metals when they need to change the direction in which a well is drilled. In Part II, you will investigate the thermal expansion of metals. Knowing about this property of metals enables the engineer to compensate for the pressure and heat that the pipes and drill bits experience during the course of oil extraction.

Part I:

1. Choose one of the other drilling engineers to work with on these experiments.
2. Grasp the copper pipe at either end and try to bend it. Repeat this process with the 1-ft steel pipe. Record your results.
3. Place 1/3 of the 6-ft section of steel pipe on the top of the lab table. One of you should then put all of your weight on this section of pipe. The other person then pushes down on the free-hanging section. (You may need an additional person to hold down the other end). Record your results.

Part II:

1. Construct the apparatus pictured below using the materials provided by your instructor. This device is used to measure the thermal expansion of a tube. Connect the metal tube to a test tube half full of water. Add glass beads to the tube to ensure consistent heating. Fasten the metal tubes in place one at a time. Fasten a clothes pin to the left side of the metal tube, closest to the test tube; this will hold the tube in place. The right side should be free to move. Place a dish under the outlet of the tube to catch the steam that will condense during the experiment. Set the circular dial to zero.



Lab set-up for measuring the thermal expansion of a long tube.

2. Using matches, light the Bunsen burner to boil the water. Steam from the water will pass through the length of the tube, heating it and causing it to expand. The expansion of the tube is amplified and measured by the rotation of the circular scale on the dial.
3. Record the change in the scale after the water has boiled for several minutes. (Make sure the water does not boil completely out of the test tube.)

Questions:

1. Which metal would make the strongest pipes?
2. Should the pipe bend? Why or why not?
3. Hypothesize about what might happen to a nine-inch diameter, one mile long string of pipe.
4. How might the ability of pipe to bend over its length without breaking aid oil extraction?
5. What was the numerical change in the scale?
6. What caused the scale to move?
7. What does this tell us about metals?
8. How might this information affect how a drilling engineer operates drilling machinery?
9. How do drilling sites keep the drill bit and piping cool? (Consult with your company mud engineer).
10. How many 30-foot sections of pipe would you need to produce a string 1 mile long?

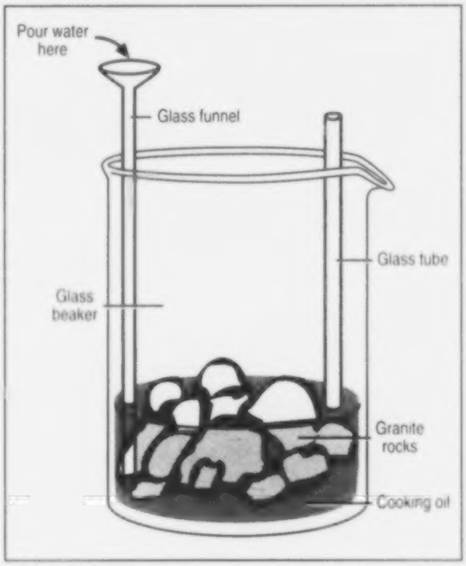
LOGGING/RESERVOIR ENGINEER

Working with a group of other logging engineers, you will investigate secondary methods of extracting oil in Part I. One method injects water and gas into an oil reservoir, which forces the oil to rise to the well base. But keep in mind that even this alternative method only yields about 30 percent of the oil contained in a well.

In Part II, you will discover how echolocation can be used to differentiate underground substrates. Logging engineers use echolocation to measure the size and shape of the oil reservoir.

Part I:

1. Choose another logging/reservoir engineer to work with on these experiments.
2. Gently pour the rock material into the glass beaker.
3. Pour the cooking oil into the same beaker.
4. Push the long-necked funnel into the beaker and hold the glass tube just above the oil level.
5. Slowly pour the water down the glass tube. Observe what happens.



Lab set-up for investigating secondary methods of oil extraction.

Part II:

1. Put on the stethoscope and place the diaphragm against the side of the tub containing sand. Strike the opposite side of the tub with the

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wooden dowel. Notice the noise it produces.

2. Repeat this process with the granite rock and diatomaceous earth tubs.
3. Now seal the tubs and rearrange them while your partner's back is turned. Have your partner try to determine the contents of each tub. Then see if you can dò the same.
4. Fill the balloon with cooking oil and tie it shut.
5. Place the balloon in the bottom of the empty tub and carefully pack sand from the sand tub on top of it.
6. Now use the sounding technique to determine the location of the oil. You may have to move the stethoscope around to different sides of the tub.
7. Seal the tub and exhange it with another logging group to see if you can discover each other's reservoir.

Questions:

1. What happened to the oil level when you added the water?
2. What does this tell you about the density of oil vs. the density of water?
3. How might this phenomenon help a reservoir/logging engineer extract oil from the ground?
4. How might soundings help logging engineers plan drilling operations?
5. How were you able to detect the oil deposit in your container?
6. Do you think you could tell whether oil deposits were of different sizes without seeing them? If so, how?

EXTRACTION/MUD ENGINEER

During this activity, you will study some of the fluid properties that help extraction/mud engineers cool, lubricate, and adjust the drill bits to prevent oil spills and blowouts. Knowing how to measure the density of fluids can help mud engineers determine how much pressure is building up in a pipe. In this experiment, you will create a solution of a given density and determine the identity of unknown fluids by measuring their densities.

Part I:

1. Density is defined as the quantity of matter in a given unit of volume. We can express this relationship mathematically as follows:

   Density = mass ÷ volume

   To determine the density of a solution or a mud, you need to determine its mass using a balance and the volume using a graduated cylinder. You then divide the volume into the mass to determine the density.
2. Obtain about 15 mL of Sample A and about 15 mL of either Sample B or Sample C as your teacher directs.
3. Weigh the graduated cylinder. Make sure that it is clean and dry. Record its mass.
4. Add 10 mL of Sample A to the cylinder. Now weigh the cylinder plus the sample. Record its mass.
5. Calculate the mass of Sample A by subtracting the value obtained in step 3 from the value obtained in step 4. Record the mass of Sample A.
6. Calculate the density of Sample A

using the equation: density = mass / volume. Record the value.

7. Repeat steps 3-6 using the other unknown sample and record all the values.
8. Referring to the table of densities that your teacher will provide, find the two substances that have densities matching the values you obtained for your unknowns. Record these names.

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WHO DOES WHAT?
STUDENT INFORMATION SHEET #1

BIOGRAPHY: ENVIRONMENTAL/CIVIL ENGINEER

R. K. Rod Bogan is an environmental/civil engineer with Phillips Oil Company. Because his long-term goal was to work for an oil company, he worked in the oil fields through both high school and college gaining first-hand experience. In college he majored in civil engineering, specializing in environmental engineering. After graduating from college, Rod started at Phillips. Phillips had an excellent training program that allowed him to spend six months in the oil field learning the (upstream) extraction end of the oil business and another six months working as a staff engineer, where he learned how to design surface equipment and operations.

Rod worked in different production jobs at Phillips for several years before he also began working in drilling. Rod currently works as a staff consulting engineer training oil industry personnel all over the world in the latest oil industry technology. Rod gives presentations and training to large and small groups on the environmental and safety concerns of the oil industry. He also does a lot of trouble-shooting whenever a problem arises. In addition, Rod has had the opportunity to do a lot of traveling.

Environmental/civil engineers are responsible for ensuring that a company's offshore oil rigs comply with environmental and safety regulations. All oil companies must obey the rules and regulations of government agencies, including the U.S. Geological Survey, the Coast Guard, the Fish and Wildlife Service, the Environmental Protection Agency, the Army Corps of Engineers, and the Bureau of Mineral Management. Everyone working on an oil rig must receive extensive training in safety, fire-prevention, fire-fighting, and environmental protection.

WHO DOES WHAT?
STUDENT INFORMATION SHEET #2

BIOGRAPHY: LOGGING/RESERVOIR ENGINEER

Because he was intrigued by man-made structures in high school, Tom Kaetzer decided to study civil engineering at the University of Illinois. His hard work in math and science courses landed him a job with Texaco Oil upon graduation. At Texaco, Tom was trained to use his engineering background to solve problems related to oil drilling. He first became a field engineer and helped install offshore platforms in the Gulf of Mexico. Several yeas later he became a petroleum engineer and received a Master"s degree from Tulane University. Tom has traveled a lot in his career, working oil fields in such locales as Columbia and the North Sea, and has held several different jobs at Texaco. But he has spent most of his time working as a logging/reservoir engineer.

As a logging engineer, Tom's primary job was to measure the spontaneous potential of the reservoir; in other words,Tom determined how well the oil would flow out of the rock and into the well pipe. Tom would send sensors down to the bottom of the hole, calculate how deep the hole was with respect to the ocean floor, and then slowly drag the sensors back up in order to take readings. One instrument, called a revisitivity tool, used an electric current to help Tom identify the type of rock in the well. A gamma ray meter let Tom find out whether the rocks contain water. While water is almost always present with oil, salt water can corrode oil equipment, which meant Tom needed to know whether a significant amount was present.

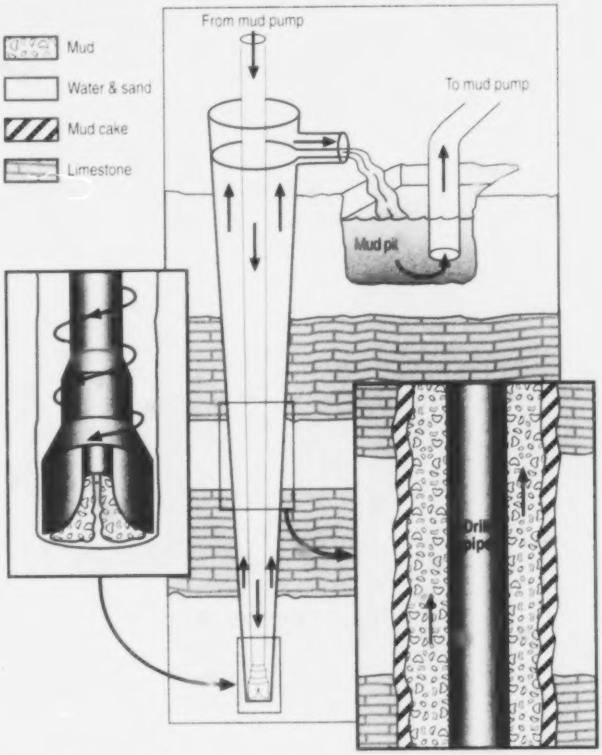
Tom worked out of an office, rather than on the rig, as a reservoir engineer. In this job, he performed a lot of calculations to determine how much oil could be obtained from a particular site. Seismic studies obtained from geologists helped him determine whether certain secondary oil extraction methods would be successful. For example, pumping water or gas down an adjoining well can force the oil in a reservoir to rise up the original well. Injecting acid into an adjoining well can also help oil move readily through the original well; the acid breaks down the rock in the reservor, making the oil more accessible.

While working as a logging/reservoir engineer, Tom used plenty of math and science. Algebra helped him compute flow equations for wells. He also used chemistry to determine the pH of acids injected into wells, and physics to perform well log analyses. Finally, Tom recorded yields for every well. Since 80 percent of an oil company's assets arc locked within its reservoir oil, Tom's computations helped Texaco maintain its economic strength.

WHO DOES WHAT?
STUDENT INFORMATION SHEET #3

BIOGRAPHY: EXTRACTION/MUD ENGINEER

Julianne Elward Berry is research chemist with Exxon. She started with Exxon after working as a high school chemistry/math teacher, a research assistant at the University of Wisconsin and U.C. Berkeley, and a research chemist in other industries. She received her Ph.D. from the University of Wisconsin. Her current research centers on improving the drilling fluids used in oil wells, commonly called mud, and on developing new, non-toxic, nonhazardous materials from which to make these fluids. At Exxon, Julianne works in a chemistry laboratory rather than on an oil rig, but her work helps those involved in the oil extraction operation. She trains mud engineers and other personnel on proper drilling fluid protocols, the latest types of mud, and the best techniques for removing rock and metal shavings from mud so that it can be recycled. Exxon uses many tons of mud to drill a well, and each barrel can cost anywhere from $10 for a barrel of mud to $100 for a barrel of oil-based mulch.



To keep the drill bit cool and ease its passage through the rock, drilling fluid or drilling mud is pumped through it. The mud flows out at the bottom of the well through the drill bit and flows back up to the surface through the space between the outside of the drill pipe and the well wall.

WHO DOES WHAT?
STUDENT INFORMATION SHEET #3 (CONT.)

Mud engineers work very closely with the driller and the geologists on the drilling team. Their job is to monitor the drilling mud system, which cools and lubricates the drill bits and creates pressure on top of the oil to prevent the oil from being wasted in a blowout or from escaping into the environment. As the well is being drilled, the drilling crew slides lengths of steel casing into the well to stop the walls from caving in and trapping the drill string, the device that holds the drill bit (see diagram).

Workers simultaneously pump a chemical mud down the middle of the drill pipe. Mud engineers don't work with mud as we know it. Drilling muds have the consistency of mud, but are actually composed of a special mixture of chemicals and clay. The mud flows out at the bottom of the well through jets in the bit and back up into the hole. The mud cools the drill bit and helps it pass through the rock, and also carries rock chippings back up to the surface, where they can be examined for signs of oil. Also, if oil is struck, the weight of the mud keeps the oil from rushing upwards in a dangerous blowout.

Extraction mud engineers work on the oil rig in 12-hour shifts, testing the mud four times a day for physical and chemical properties, such as density, viscosity, fluid loss, pH, and temperature. The tests can take two to three hours to complete. In addition, mud engineers determine the best techniques for separating the rock and metal shavings from the mud, so that it can be recycled and pumped back into well. Mud engineers also work closely with geologists, examining the rocks delivered to the surface of the well by the mud to determine whether the well has hit oil or whether deeper drilling is required.

WHO DOES WHAT?
STUDENT INFORMATION SHEET #4

BIOGRAPHY: DRILLING ENGINEER

A Houston native, Juanita Alvarez found herself drawn to the oil industry, and particularly to what she now refers to as the "upstream" sector of the industry—those who are directly involved with the drilling and extraction of oil. To position herself properly to get a job with an operating company, Juanita interned with an oil company while studying mechanical engineering at Rice University. She joined the company as a drilling engineer after graduation, and is now a manager of international drilling at the company's headquarters.

Juanita has found that drilling engineers possess a unique attitude toward their role in the extraction process—they seem born to drill for oil or gas. Drilling engineers are responsible for the design of the well; drilling managers oversee the construction of the well. While the drilling engineers work closely with other members of the extraction team, it ultimately comes down to the drilling department to design the well and execute the drilling program in a safe, cost-effective, and environmentally sound manner. It is also up to the drilling engineer to acquire the optimum amount of geotechnical and petrotechnical information, and to leave the wellbore in a condition that guarantees that productive wells will yield the maximum commercial value to the company.

A considerable amount of work must be accomplished to prepare drilling sites. Obviously, one of the first tasks is to build the oil rig and assemble the various drilling systems, which include hoisting, rotating, circulating, power, and blowout prevention systems. Once the rig has been built, drilling can progress by one of two routes. In straight-hole drilling, an array of specialized down-hole tools located in the lower drill stem is used to regulate the weight on the bit and the rotation speed according to the parameters set during exploration. The other technique, known as directional drilling, usually occurs when space is limited at a particular site, or when a formation cannot be reached from directly above. Under these conditions, drilling engineers may opt to deviate the direction in which the hole is drilled in order to penetrate a specific target formation. To ensure that drilling proceeds smoothly, drilling engineers will continuously monitor the activity and recommend changes as appropriate. For example, they may replace or modify drill bits, bottom hole assemblies, mud properties, hydraulics, or casing strings to adjust to the conditions encountered during drilling.

Because oil sites may be located all over the world, drilling engineers must be willing to travel extensively in order to investigate new sites and monitor drilling operations. And even when at home, drilling engineers must be on 24-hour call in case a problem occurs during drilling. But for Juanita and other motivated, project-oriented people, the life of a drilling engineer is ideal.

The Environment

Students will explore the marine environment and ecosystem, focusing on how the living organisms interact with each other and the physical environment they live in. They will then examine how offshore oil drilling affects this environment.

Time Needed: Five days

Unit Description:

During this unit, students will see how ecosystems comprise a complex series of interactions among organisms and the physical environment they inhabit. Students will learn to appreciate how a change in one part of ecosystem can affect the rest of the ecosystem, and will see that human intervention can be a major cause of such changes. Using what they have learned about oil development and production during this block, students will draw conclusions about the environmental consequences of offshore oil drilling.

The first activity, **The Marine Ecosystem**, introduces students to the biotic and abiotic components of this ecosystem—the animals, plants, minerals, chemistry, and physical geology of the continental shelf. Students explore the physical parameters of the marine environment and how marine organisms adapt to these conditions.

Students will focus on plankton, one of the most common types of marine organisms, during the second activity, **The "Enlightened" Shrimp**. By examining the behavior of brine shrimp, a form of freshwater zooplankton, students will gain a microcosmic view of the transfer of energy within the marine environment. This knowledge will help them understand the macrocosmic impact that an offshore oil platform can have on the marine food web.

In the next activity, **Cleaning Up an Oil Spill**, students will use what they have learned about oil development and production during this block to draw conclusions about the environmental consequences of offshore oil drilling. Teams of students will develop and test methods of cleaning up an oil spill on a laboratory scale. They will then compare these methods to those used to clean up actual oil spills on the open sea.

Finally, students will simulate a regulatory hearing that will allow them to combine the economic, environmental, and industrial knowledge that they have obtained during this block. During this hearing, students will decide whether to issue a permit to an oil company that wants to explore for, produce, and transport oil at a given site.

MATERIALS

PART A: The Marine Ecosystem
- index cards
- large pieces of butcher paper or posterboard

PART B: The "Enlightened" Shrimp
- a variety of light sources
- clear plastic tubing
- petri dishes
- cloth
- heavy paper
- eye droppers
- hand lenses
- binocular microscopes
- brine shrimp
- overhead transparency
- marking pens

PART C: Cleaning Up an Oil Spill
- plastic container
- artificial sea water
- dyed vegetable oil

PART D: Regulatory Hearing for Offshore Oil Development
- Draft environmental impact statement: *South Shore Canary Island Proposed Oil and Gas Lease Sale* (see Appendix)
- Project Wild Aquatic materials
- *Utilizing Coastal Resources*
- Energy and Society activities
- Chem Com simulation
- Jason Project activities

TEACHER PRELAB PREPARATIONS FOR PART A:

Objectives:

Students will brainstorm in groups over a series of questions to learn details of the marine ecosystem.

Set-Up:

1. Prior to lab, make sure that the students are familiar with the types of communities that exist in the marine environment. They should understand how food pyramids, food chains, and food webs work, and should know about the basic roles that different plants and animals play within these systems. Students will also benefit from some basic knowledge of oceanography, including the properties of sea water, currents, tides, and sea floor topography. Before the brainstorming activity, review this background material or provide resources so that the students can research some of these subjects independently or in groups.
2. On large index cards, write out the following five brainstorming topics:

- What are some of the different habitats that support communities of marine organisms?
- What kinds of food chains and webs exist in marine communities?
- How do the topography, depth, and composition of the ocean floor determine the variety of oceanic flora and fauna that live there?
- What is the composition of sea water? What factors influence its make-up? How do oceanic temperature and pressure vary at different depths?
- What causes the flow of nutrients and energy in the ocean to be concentrated around continental margins and near the surface of oceans?

Procedure:

1. Copy and distribute the Student Materials.
2. Ask the class to identify the major living communities in the marine envrionment. Then ask the class to identify the physical parameters in which each group of organisms live.
3. Divide the class into groups of five or six students. Give each group a topic related to the marine environment for brainstorming, and have them identify as many factors relating to their topic as possible. Students should record their ideas on the large pieces of butcherpaper or posterboard so that they can be posted.
4. After ten minutes, reconvene the class and have each group present its list. Compare and combine the five lists to create an overview of what the students currently know about the marine environment.
5. Tell the students to read over the Student Information Sheet. Do they have any adjustments to make to their list? Help the students revise their list to present a more accurate view of the marine environment.

FOR PART B:

Objectives:

Students will examine a small, but important, member of the marine community—plankton. Here, plankton is represented by the brine shrimp, a freshwater organism that serves as the basis of a very specific food web. During this activity they will investigate brine shrmip behavior, study the anatomy of the shrimp, and determine the role that its relatives play in the marine ecosystem.

Set-Up:

1. Review with the students the role that lower-level organisms play in food pyramids. Phytoplankton serve as producers, generating energy from nutrients in the water and sunlight. Zooplankton occupy the next level; as primary consumers, they feed on phytoplankton and serve as prey for those above them in the pyramid. Brine shrimp are a form of zooplankton. Remind them that lower levels of food pyramids contain the largest number of organisms, because at each step a fraction of the energy is consumed and cannot be recovered. Lower-level organisms must be more flexible to support the organisms above them in the food pyramid.
2. Live brine shrimp are available at aquarium shops. You can feed them a weak yeast culture and keep them for several days in aerated containers.
3. Brine shrimp are members of the phylum Arthropoda, subphylum Crustacea, and the class Branchiopoda. Other arthropods include spiders, ticks, mites, barnacles, crabs, sow bugs, millipedes, centipedes, and insects.

Procedure

1. Copy and distribute the Student Materials.
2. Divide students into groups of five or six students. Students will first test whether the shrimp prefer a light or dark envrironment. They will

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then study the anatomy of the shrimp.

3. Provide reference materials to assist the students as they draw the shrimp and determine their phyium and class.
4. After the laboratory, discuss the transfer of energy in a marine environment with the class. Ask the students to hypothesize about the impact that an offshore oil rig might have on this environment.

For Part C:

Objective:

In this activity, students will simulate an oil spill on a small scale and investigate procedures to clean it up. This investigation was adapted from the Salters' Science Unit "Making Use of Oil."

Procedure:

1. Copy and distribute the Student Materials.
2. Divide the students into teams of three or four students.
3. Students will first create an oil spil. They will then develop a strategy for removing the oil layer using common materials found in the lab. Once the group has reached consensus on a plan, the team recorder should enter it on an overhead transparency or chalk board.
4. Ask the students to compare and contrast the different plans, and perhaps to offer some new suggestions based on the discussion.
5. Students will then collect the supplies necessary to test their plans. Each team should carry out their plan and record the results.
6. When all the experiments are complete, ask the students to present their results to the class. Encourage the students to evaluate how successful their method was.

For Part D:

Objective:

In the culminating project for this block, students will apply the knowledge that they gained in each unit by participating in a mock regulatory hearing. Students will enact the roles of different experts on the committee to decide whether offshore oil drilling should be allowed at a particular location.

Set-Up and Organization:

1. Students will divide into seven groups representing the different people involved in a regulatory hearing. The groups are listed in the Student Instructions.
2. Each member of the committe will need to address several topics by reading reference materials on the subject and compiling a short report for the members of the committee. The topics are listed in the Student Instructions.
3. The different roles available for students are listed in the Student Instructions. If you wish, you may make role cards specific to each role to hand out to students individually.
4. Allow the students at least one day to carry out their research and prepare statements. Students should then give three to five minute presentations to their groups.

5. Working cooperatively, the members of each committee will write a regulatory hearing presentation. Each group will present its argument and justify the committee's position during the hearing.
6. Students will then vote on whether or not the permit should be issued. Encourage the class to vote as the members of the groups they represent, rather than as they themselves, might vote.

The Environment

Part A: The Marine Ecosystem

OBJECTIVES:

Your group will generate ideas and information about a specific aspect of the marine environment using brainstorming techniques. You will then share your information with the rest of the class and help develop a comprehensive picture of the marine envrionment.

INSTRUCTIONS:

1. Divide into groups of five or six students and obtain a brainstorming topic from your instructor.
2. Assign one member of the group to be the recorder, one to be the reporter, and one to be the coordinator.
3. You will have ten minutes to brainstorm. On the large piece of paper, have the recorder write down all of the ideas generated on the topic. Remember that in brainstorming, any suggestions are good ideas. Seemingly preposterous ideas can turn out to be the most valuable. The coordinator should make sure that everyone in the group respects the suggestions made by others, and should ensure that each person in the group contributes at least one idea. Pictures or drawings may help you illustrate certain aspects of the marine environment.
4. After ten minutes, you will join your classmates for discussion. The reporter will present your ideas to the rest of the class. Give your list to your instructor to post with the lists created by other groups.
5. After the discussion, reconvene your group and read over the Student Information Sheet as a group. Afterwards, decide how to rework your list to reflect the new material that you have learned.
6. Back in the large group, have the reporter explain any changes you made to your list.

THE MARINE ECOSYSTEM
STUDENT INFORMATION SHEET

THE OCEAN ENVIRONMENT

The world's oceans cover approximately 70 percent of the earth's surface. Although sailors have thoroughly explored the surface of the ocean, scientists still know very little about what goes on beneath the surface. Only recently have scientists observed the properties of ocean water and the special ways that marine life must adapt to it.

Physical Properties

Ocean water has an average salinity of approximately 3.5 percent by weight. Sodium chloride is the most common salt present, though ocean water also contains salts formed from sulfate, magnesium, calcium, and potassium. Salinity varies from place to place in the ocean, depending on rates of evaporation and precipitation, incoming fresh water, and depth.

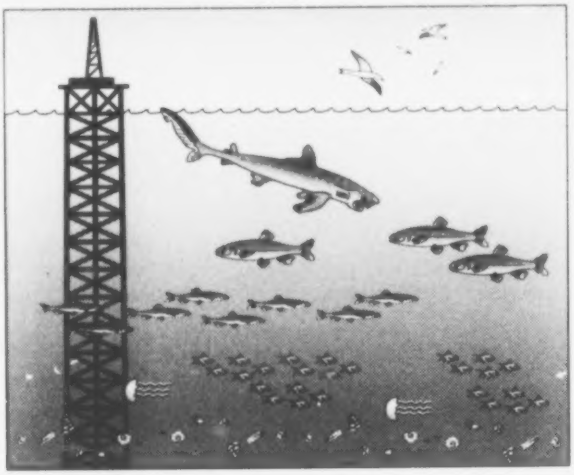
The sun is the major source of heat for the ocean, which means that temperatures are highest near the surface of the ocean. Between 30 meters and 800 meters deep, the temperature decreases rapidly, to approximately 5°C. Below this level, the temperature stays just above freezing. Latitude and current direction also affect water temperature. The closer the water is to the equator, the warmer the water. In addition, warm currents carrying water from the equator to the poles usually flow on the east side of continents. Cold currents along the west coasts of continents carry polar waters toward the equator. The motion of the currents explains why surfers in Los Angeles, California must wear wetsuits most of the year, while in Florida, people can surf without a wetsuit in the middle of winter.

While temperature decreases with depth, pressure increases as the overlying mass of water puts more weight on the water below it. For every ten meters, pressure increases by one atmosphere of pressure. An atmosphere is the average pressure of the atmosphere at sea level, 14.7 lb/in2 or 1 Kg/cm^2. So 100 meters below the surface of the ocean, the pressure is ten atmospheres. The conditions only 200 meters below the surface seem severe and inhospitable to humans, and to many of the other types of organisms that we recognize as ocean inhabitants. The high pressure, along with the darkness and cold temperatures prevalent at these depths, has forced many interesting adaptations. But the conditions also make exploring this world difficult; not only are the organisms fragile, but developing equipment that can operate under these extreme conditions is difficult.

Nutrients in the ocean come from decomposing organisms on the ocean floor and from rivers that empty into the oceans. Rivers carry elements dissolved from rocks and land masses, along with organic wastes flushed into them by man, into the ocean.

The Marine Ecosystem

Ocean food chains rely on phytoplankton—small organisms that receive their energy from the sun. The phytoplankton are eaten by the zooplankton—tiny animals or the larval forms of larger animals. Together, the planktonic organisms serve as the foundation of the marine food pyramid. In fact, many whales, the largest organisms in the sea, are plankton feeders. Most marine life is found near the continental margins and in the upper part of the ocean waters, where light is available to a large population of producers, such as seaweed, kelp, and plankton. In some parts of the ocean, plumes of water rich in hydrogen sulfide rise from vents in the ocean floor. These regions support a special group of animals, such as giant tube worms, clams, shrimp, and crabs, that survive by feeding on a particular type of bacteria that uses hydrogen sulfide for food. The few animals that inhabit the deepest parts of the ocean feed on the decomposing bodies of organisms from the upper levels and on the other organisms that live in this cold, dark environment.



The ocean food chain.

References

American Geological Institute. (1984). *Investigating the Earth, 4th edition.* Houghton Mifflin Co.
Cooney, Pasachoff, and Pasachoff. (1990). *Earth Science.* Scott, Foresman and Co.
Maton, Anthea, et. al. (1993). *Exploring Planet Earth.* Englewood Cliffs, NJ: Prentice-Hall.
Turekian, Karl K. (1968). *Oceans.* Prentice-Hall, Inc.

The Environment

Part B: The "Enlightened" Shrimp

OBJECTIVES:

In this activity, you will design an experiment to determine how brine shimp respond to a light or dark environment. You will also observe the anatomy of the shrimp, and determine its phylum, class, and role in the marine food web.

INSTRUCTIONS:

1. Divide into teams of five or six students and collect the materials from your instructor.
2. Answer the discussion questions as you complete the activity.
3. Use the materials provided by your instructor to design an experiment to determine whether the shrimp prefer a light or dark environment. Record your design on an overhead transparency. Your teacher will lead a discussion of the plans proposed by the various groups.
4. Carry out your experiment and record how the shrimp respond.
5. Investiage how the shrimp respond when you shine light from below the petri dish.
6. Using a binocular microscope or hand lens, observe the brine shrimp closely and draw its anatomy. Your group should decide on a suitable drawing. Then, compare the drawing with the diagram of the brine shrimp on the Student Information Sheet and label your drawing. Finish answering the discussion questions.
7. Rejoin your class to discuss how an offshore oil platform could affect the marine environment.

DISCUSSION QUESTIONS:

1. Do most of the brine shrimp swim with their dorsal or ventral side up?

2. What is your experiment design?

3. Did your brine shrimp prefer a dark or a light environment? Explain how you could tell.

3. What do the shrimp do in response to light from below?

4. Describe the brine shrimp anatomy

5. Using the Student Information Sheet as a resource, determine the brine shrimp's phylum and class? What are some other members of its phylum?

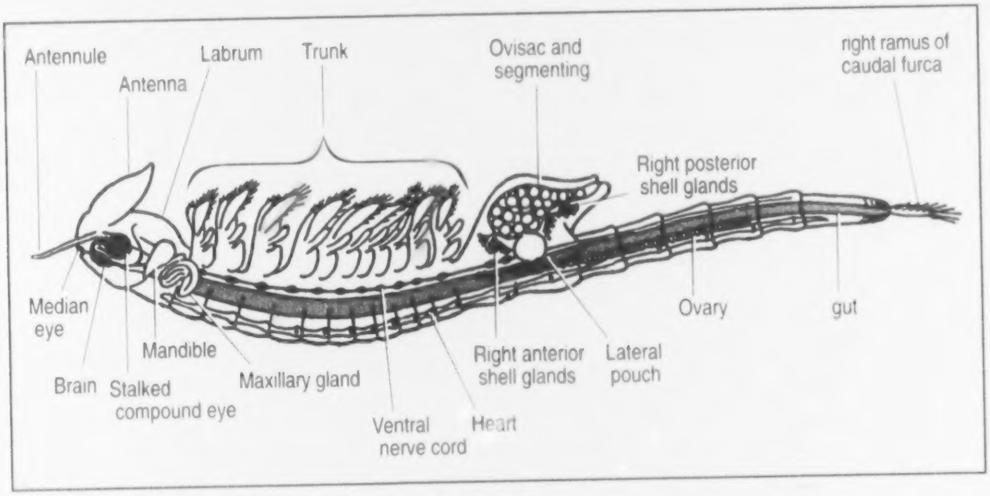
6. In the space below, draw a diagram showing how energy is transferred in the marine environment. You should include planktonic organisms, small fish, molluscks, larger fish, and marine mammals in your food web or chain.

7. How might an offshore oil drilling platform affect the marine environment? List positive and negative effects.

THE "ENLIGHTENED" SHRIMP
STUDENT INFORMATION SHEET

This laboratory has introduced you to a small, but very important member of the marine food web—plankton. In this laboratory, plankton was represented by the tiny brine shrimp, which is actually a form of zooplankton. Zooplankton are slightly larger than phytoplankton; in fact, they typically feed on phytoplankton, and in turn serve as food for animals residing above them in the food chain.

Brine shrimp, along with brine flies, are the only animals that have adapted to live in the highly salty water of brine lakes, such as the Great Salt Lake in Utah and Mono Lake in California. Though this may seem a harsh environment by our standards, brine shrimp thrive in these lakes, as they are the only aminals that can feed on the various forms of phytoplankton that have adapted to this environment. Consequently, they form the basis of an active ecosystem, providing an important source of food to many species of birds that live or migrate through the brine lakes.


Antennule
Antenna
Labrum
Trunk
Ovisac and segmenting
right ramus of caudal furca
Right posterior shell glands
Median eye
Mandible
Brain
Stalked compound eye
Maxillary gland
Ventral nerve cord
Heart
Right anterior shell glands
Lateral pouch
Ovary
gut

Brine shrimp: Artemia

As you discovered in this laboratory, brine shrimp display positive phototaxis. In other words, they are attracted to light, and will orient themselves so that their ventral side is pointed toward the light. Animals react to light in a variety of ways, and for many different reasons. Some animals move away from light in order to hide from predators. Some prefer to move toward light, as their food is typically active during the day. Why do the brine shrimp behave as they do? Well, consider what we learned about plankton's habitat in the last laboratory. Phytoplankton need sunlight to photosynthesize; thus, they are typically located near the surface of water, where they can find the most sunlight. Brine shrimp, which feed on phytoplankton, may have developed this response to light to help

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them find food. The shrimp not only can tell where the light is, but respond to it by orienting themselves in the best possible position to feed.

Compare your drawing of the brine shrimp to the drawing on this sheet and label the different parts of the organism. While brine shrimp are certainly much smaller than the shrimp that we eat, they are related to saltwater shrimp. For example, they both have a hard outer covering known as an exoskeleton. Their bodies are both divided up into three segments: a head, a thorax, and an abdomen. Notice also that the tail of the brine shrimp is jointed, and that it also has a jointed antenna to help it sense its environment. What other characteristics of the brine shrimp can you point out? What phylum do you think it belongs to? What might its subphylum be? (Hint: it is the same as its larger, saltwater relative)? Can you name some of its more distant relations (ie. animals in the same phylum and subphylum)?

References:

Cash, David. 1994. *Hands On!* 17.2: 11-13.
Maton, Anthea, et. al. 1993. *Parade of Life: Animals.* Englewood Cliffs, NJ: Prentice Hall.
Weiss, Howard M. and Dorsey, Michael W. 1979. *Investigating the Marine Environment,* vol. 2. Groton, CT: Project Oceanology.
Whitten, Richard H. and Pendergrass, William R. 1980. *Carolina Protozoa and Invertebrates Manual.* Burlington, NC: Carolina Biological Supply Company.

The Environment

Part C: Cleaning Up an Oil Spill

OBJECTIVES:

A large amount of crude oil is produced by offshore oil wells and transported by sea tankers. While petroleum companies take every precaution to prevent oil spills, accidents inevitably happen. In this activity, you will investigate ways to clean up a simulated oil spill in the laboratory, and will learn some of the steps taken by petroleum companies to deal with oil spills on the open sea.

INSTRUCTIONS:

1. Divide into teams of three or four students. As you proceed through the activity, answer the discussion questions.
2. Measure the volume of artificial sea water (in mL) needed to fill a plastic container to a depth of 1.5 cm and then measure out enough dyed vegetable oil to cover the surface of the sea water.
3. As a team, discuss ways to remove the oil layer using common materials found around the lab. Decide on one plan that you will follow.
4. The team recorder should enter the team plan on an overhead transparency or chalk board. Your teacher will lead a discussion to compare and contrast the plans presented. Additional plans may be conceived of as strategies are discussed.
5. Following the discussion, try out your experiment and record the results.
6. Report your method and its results to your class. Discuss how successful the various methods developed by the groups were.

DISCUSSION QUESTIONS

1. What were the volumes of sea water and oil that you used?
2. Describe the mixture of sea water and oil. Is the oil miscible (capable of being mixed) or immiscible?
3. Which is less dense—the oil or the seawater? How do you know?
4. Describe the method your group developed to clean up the oil. How successful was your method?
5. Which method of cleaning up the oil was most successful?

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The Environment

Part D: Regulatory Hearing on Offshore Oil Development

OBJECTIVES:

This activity allows you to apply all of the information that you have learned about offshore oil drilling by participating in a mock regulatory hearing. During this hearing, you will decide whether to allow a petroleum company to explore for, produce, and transport offshore oil at a South Shore Canary Island site. You will serve as an expert on a particular committee, and will provide information to the other committee members on several assigned topics. Your committee will then prepare a position statement to deliver at the hearing, arguing either for or against issuing an offshore oil exploration and drilling permit.

INSTRUCTIONS:

1. You will divide into seven groups representing people who either support or oppose issuing a permit to drill at the South Shore Canary Island site. Within each group, you can play several different roles. The groups and roles available are listed below:

- **Project proposers**
  oil company executive
  oil company geologist
  drilling expert
  oil company lawyer
- **Local business I**
  labor leader
  unemployed welder
  land use planner
- **Local business II**
  fishing union representative
  tourism industry representative
  real estate representative
- **Environmental organization representatives**
  Green Peace lawyer
  Save the Oceans chairperson
  California Public Interest Research Group (CALPIRG) college student
- **Government regulatory agency representatives**
  Environmental Protection Agency official
  wildlife/fisheries biologist
- **Elected officials**
  mayor
  supervisor
  senator
  assembly representative
- **Area residents**
  mother of two children and owner of beach home
  college-age surfer
  high school science teacher

2. After learning which group you have been assigned to, look over the roles available and choose one to play. Or, alternatively, your instructor will provide you with a role card listing your part. Regardless, you will need to research your role com-

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pletely and prepare a convincing, well-substantiated argument supporting your position. You will present this information to your committee, and provide a written report of your research to your instructor. An environmental impact statement on the proposed project and other reference materials will be provided for your research. You may also want to consult additional materials.

3. After each expert has shared his/her research with the other committee members, the committee will discuss the environmental topics and rank them in order of importance. Together, the committee members will prepare a three to five minute presentation representing the group's point of view on whether to issue a permit. You will have one class period to prepare your argument. You may choose one spokesperson for your group or divide up the time allotted so that each of you can present part of the argument. Be prepared to back up your argument with facts.
4. At the hearing, you will be expected to deliver your position statement within the allotted time period. Two students designated hearing officers will conduct the hearing. The hearing officer designated as "timer" will cut off speakers when the time allotted for each presentation has passed.
5. After the class has heard all the arguments, it will vote on whether to issue the offshore oil exploration and drilling permit. Remember to stay in character, voting the way someone in your role would vote after hearing the arguments presented.

COMMITTEE ROLES:

Project Proposers

1. Oil company executive
   Ascertain the effect that an onshore support area for a drilling crew and transportation to and from the oil drilling platform might have on the local environment. Propose different methods of transferring extracted oil from the platform to the shore or refinery (such as pipelines, transfer vehicles, and oil tankers). *Hint: Review what you have learned about how offshore oil drilling can affect nearby land areas. Research how oil companies transport oil from platforms to refineries.*
2. Oil company geologist
   Determine the liklihood of oil spills and natural oil seepage at this site, and discuss how it could affect the area. Discuss how suitable the site is for offshore drilling, taking into account geologic stability and existing onshore activities. *Hint: Review what you have learned about oil seeps and spillage. Also, review how geologic factors impact offshore dilling. Assess how an offshore oil drilling platform might affect local activities, such as tourism, fishing, shipping, and migration routes.*
3. Drilling expert
   Determine the ways that an offshore oil drilling operation might affect the marine envrionment. In particular, examine how the environment could

be altered by oil exploration and the presence of a drilling platform. *Hint: Review what you have learned about the mechanics of offshore oil drilling. Focus on how the procedures alter the marine environment.*

4. Oil company lawyer
   Determine the liklihood of oil spills and natural oil seepage at this site, and discuss how they could affect the area. Discuss how suitable the site is for offshore drilling, taking into account geologic stability and existing onshore activities. *Hint: Review what you have learned about oil seeps and spillage. Also, review how geologic factors impact offshore dilling. Assess how an offshore oil drilling platform might affect local activities, such as tourism, fishing, shipping, and migration routes.*

Local business I

1. Labor leaders
   Determine the liklihood of oil spills and natural oil seepage at this site, and discuss how it could affect the area. Propose different methods of transferring extracted oil from the platform to the shore or refinery (such as pipelines, transfer vehicles, and oil tankers). *Hint: Review what you have learned about oil seeps and spillage. Research how oil companies transport oil from platforms to refineries.*
2. Unemployed welder
   Ascertain the effect that an onshore support area for a drilling crew and transportation to and from the oil drilling platform might have on the local environment. Determine the ways that an offshore oil drilling operation might affect the marine envrionment. *Hint: Review what you have learned about how offshore oil drilling can affect nearby land areas. Also, review the mechanics of offshore oil drilling. Focus on how the procedures can alter the marine environment.*
3. Land use planner
   Examine how the marine environment could be altered by oil exploration and the presence of a drilling platform. Discuss how suitable the site is for offshore drilling, taking into account geologic stability and existing onshore activities. *Hint: Review what you have learned about the mechanics of offshore oil drilling. Focus on how the procedures alter the marine environment. Also, review how geologic factors impact offshore dilling. Assess how an offshore oil drilling platform might affect local activities, such as tourism, fishing, shipping, and migration routes.*

Local business II

1. Fishing union representative
   Determine the ways that an offshore oil drilling operation might affect the marine envrionment. Determine the liklihood of oil spills and natural oil seepage at this site, and discuss how it could affect the area. *Hint: Review what you have learned about the mechanics of offshore oil drilling. Focus on how the procedures alter the environment. Also, review the effects of oil seeps and*

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spillage on the marine environment.

2. Tourism industry representative
Determine the ways that an offshore oil drilling operation might affect the marine envrionment. In particular, examine how the environment could be altered by oil exploration and the presence of a drilling platform. Discuss how suitable the site is for offshore drilling, taking into account geologic stability and existing onshore activities. *Hint: Review what you have learned about the mechanics of offshore oil drilling. Focus on how the procedures alter the marine environment. Also, review how geologic factors impact offshore dilling. Assess how an offshore oil drilling platform might affect local activities, such as tourism, fishing, shipping, and migration routes.*
3. Real estate representative
Determine the liklihood of oil spills and natural oil seepage at this site, and discuss how it could affect the area. Propose different methods of transferring extracted oil from the platform to the shore or refinery (such as pipelines, transfer vehicles, and oil tankers). *Hint: Review what you have learned about oil seeps and spillage. Research how oil companies transport oil from platforms to refineries.*

Environmental organization representatives

1. Greenpeace lawyer
Determine the liklihood of oil spills and natural oil seepage at this site, and discuss how it could affect the area. Discuss how suitable the site is for offshore drilling, taking into account geologic stability and existing onshore activities. *Hint: Review what you have learned about oil seeps and spillage. Also, review how geologic factors impact offshore dilling. Assess how an offshore oil drilling platform might affect local activities, such as tourism, fishing, shipping, and migration routes.*
2. Save the Oceans chairperson
Determine the ways that an offshore oil drilling operation might affect the marine envrionment. Ascertain the effect that an onshore support area for a drilling crew and transportation to and from the oil drilling platform might have on the local environment. *Hint: Review what you have learned about the mechanics of offshore oil drilling. Focus on how the procedures alter the marine environment. Also, review how offshore oil drilling can affect nearby land areas.*
3. CALPIRG college student
Determine the ways that an offshore oil drilling operation might affect the marine envrionment. In particular, examine how the environment could be altered by oil exploration and the presence of a drilling platform. Propose different methods of transferring extracted oil from the platform to the shore or refinery (such as pipelines, transfer vehicles, and oil tankers). *Hint: Review what you have learned about the mechanics of offshore oil drilling. Focus on how the procedures alter the marine*

environment. Research how oil companies transport oil from platforms to refinery.

Elected officials

1. Mayor

   Ascertain the effect that an onshore support area for a drilling crew and transportation to and from the oil drilling platform might have on the local environment. Discuss how suitable the site is for offshore drilling, taking into account geologic stability and existing onshore activities. *Hint: Review how offshore oil drilling can affect nearby land areas. Also, review how geologic factors impact offshore dilling. Assess how an offshore oil drilling platform might affect local activities, such as tourism, fishing, shipping, and migration routes.*
2. Supervisor

   Determine the ways that an offshore oil drilling operation might affect the marine envrionment. In particular, examine how the environment could be altered by oil exploration and the presence of a drilling platform. *Hint: Review what you have learned about the mechanics of offshore oil drilling. Focus on how the procedures alter the environment.*
3. Senator

   Determine the liklihood of oil spills and natural oil seepage at this site, and discuss how they could affect the area. Propose different methods of transferring extracted oil from the platform to the shore or refinery (such as pipelines, transfer vehicles, and oil tankers). *Hint: Review what you have learned about oil seeps and spillage. Research how oil companies transport oil from the platform to the refinery.*
4. Assembly representative

   Determine the liklihood of oil spills and natural oil seepage at this site, and discuss how they could affect the area. Discuss how suitable the site is for offshore drilling, taking into account geologic stability and existing onshore activities. *Hint: Review what you have learned about oil seeps and spillage. Also. review how geologic factors impact offshore dilling. Assess how an offshore oil drilling platform might affect local activities, such as tourism, fishing, shipping, and migration routes.*

Government regulatory agency representatives

1. Environmental protection agency

   Determine the liklihood of oil spills and natural oil seepage at this site, and discuss how it could affect the area. Propose different methods of transferring extracted oil from the platform to the shore or refinery (such as pipelines, transfer vehicles, and oil tankers). *Hint: Review what you have learned about oil seeps and spillage. Research how oil companies transport oil from platforms to refineries.*
2. Wildlife/fisheries biologist

   Determine the ways that an offshore oil drilling operation might affect the marine envrionment. In particular, examine how the environment could be altered by oil exploration and the presence of a drilling platform. *Hint: Review what you have learned about the mechanics of offshore oil drilling. Focus on how the procedures alter the marine environment.*

Area residents

1. Mother of two children and owner of beach home
   Discuss how suitable the site is for offshore drilling, taking into account geologic stability and existing onshore activities. Ascertain the effect that an onshore support area for a drilling crew and transportation to and from the oil drilling platform might have on the local environment. *Hint: Review how geologic factors impact offshore dilling. Assess how an offshore oil drilling platform might affect local activities, such as tourism, fishing, shipping, and migration routes. Also, review how offshore oil drilling can affect nearby land areas.*
2. College-age surfer
   Determine the liklihood of oil spills and natural oil seepage at this site, and discuss how it could affect the area. Examine the ways that an offshore oil drilling operation might affect the marine envrionment. *Hint: Review what you have learned about oil seeps and spillage. Also, review what you have learned about the mechanics of offshore oil drilling. Focus on how the procedures alter the marine environment.*
3. High school science teacher
   Examine how the marine environment could be altered by oil exploration and the presence of a drilling platform. Discuss how suitable the site is for offshore drilling, taking into account geologic stability and existing onshore activities. *Hint: Review what you have learned about the mechanics of offshore oil drilling. Focus on how the procedures alter the marine environment. Also, review how geologic factors impact offshore dilling. Assess how an offshore oil drilling platform might affect local activities, such as tourism, fishing, shipping, and migration routes.*

South Shore Canary Island
Proposed Oil and Gas Lease

Draft Environmental Impact Statement

I. *PURPOSE AND NEED FOR ACTION*

A. Purpose

The purpose of this proposed sale is to offer blocks of up to nine square miles in area, to lease for oil and gas exploration and development on available acreage offshore of South Canary Island.

The United States Department of the Interior is required to manage the exploration and development of oil and gas resources on the Outer Continental Shelf (OCS).

This Environmental Impact Statement is an analysis of potential environmental impacts from the proposed project. The hypothetical facility locations and transportation scenarios described represent assumptions that were made for purposes of analysis only, and serve as a basis for identifying characteristic activities that may result from the proposal, and any resulting environmental impacts and multiple-use conflicts. These assumptions do not represent a recommendation, preference, or endorsement of any sites or scenarios given. The assumptions are hypothetical only.

B. Need for Action

This proposed action responds to the nation's need for reliable energy supplies. Development of OCS resources is an integral part of a program designed to meet these objectives. The U.S. Geological Survey (USGS) estimates that large undiscovered recoverable oil resources exist in the OCS. The South Canary Island Site is thought to consist of a sedimentary basin containing hydro-carbon bearing formations.

C. Regulatory Framework—Laws and Agencies

The Department of the Interior is responsible for administering the OCS Oil and Gas Leasing and Development Program. Under this program, the Outer Continental Shelf Lands Act (OCSLA) established federal jurisdiction over submerged lands on the OCS seaward of state boundaries. The Act provides guidelines for implementing an OCS oil and gas exploration and development program. It provides guidelines for granting leases, and includes administration of the Offshore Oil Pollution Compensation Fund, Fishermen's Contingency Fund, Best Available and Safest Technology, and Air Quality. Twelve other environmental protection laws apply to this action, and are administered under the OCSLA. Other federal agencies responsible for certain aspects of offshore development include the U. S. Environmental Protection Agency, U. S. Army Corps of

South Shore Canary Island Proposed Oil and Gas Lease (Cont.)

Engineers, Department of Commerce, Department of Transportation, Department of Energy, Department of Labor, and Attorney General.

D. History of Oil and Gas Leasing, Exploration, and Development Offshore South Shore Canary Island

In 1970, Sale X-10 in the Canary Island area was held, resulting in the sale of four leases within the Sale Area called the East Canary Island Basin. Three exploratory wells were drilled between 1972 and 1977 on two of the four blocks leased. Hydrocarbons encountered at that time were not considered to be recoverable, and the leases were relinquished in 1978. Sale X-10 also resulted in eight leases in the West Canary Island Basin, west of Canary City. Four exploratory wells were drilled between 1973 and 1978, but no hydrocarbons were encountered. However, thermally produced hydrocarbons were recovered from a gravity core. The leases were relinquished in 1978. There is a potential for gas in this area, and the geologic conditions are favorable for the occurrence of petroleum.

E. Estimated Oil and Gas Reserve/Production Potential

A significant oil and gas discovery is possible in the Canary Island area. This is based on the geology and depositional environment of the area and is supported by the seismic exploration efforts performed to date in the region. Further, in order to support the exploration and development of oil and gas reserves in this area, a significant discovery is required to result in a commercial venture.

Based on the geological interpretations to date and the oil/gas discovery size needed to justify the exploration and development risks, the following range in oil and gas discovery is estimated:

1. Water Depth Range: 350 m to 1250 m.
2. Estimated Oil in Place: 300 million to 1.5 billion barrels (stock tank barrels and/or barrel-oil-equivalents of gas; where 1000 cubic feet gas = 1 stock tank barrel of oil).
3. Estimated Recoverable Oil: 100 to 500 million barrels
4. Estimated Producing Rate: 40,000 to 100,000 barrels/day
5. Estimated Field Life: 10 to 25 years
6. Number of Development Wells: 20 to 50 wells
7. Estimated Total Investment: $600 million to $3 billion

The following are key assumptions used in estimating the above ranges in development criteria.

1. Assume the oceanographic conditions, earthquake design criteria, and environmen-

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tal/safety/regulatory requirements are similar to other developments in the area.

2. The West Basin will likely require a larger discovery as it will likely be in deeper water and require a larger platform.
3. Approximately 30% of the original oil in place will be recovered. Additional recovery will require enhanced oil recovery techniques and, as such, extend field life and require significant additional expenditures.
4. A finding and development cost of $5 to $10 per barrel of oil equivalent produced, is assumed.

F. Administrative Events Leading Up to the Proposal

At this time, a proposal is being advanced to further explore both the East and West Canary Island Basins by a lease schedule in 1994-1999. During this time further exploratory wells would be drilled, with evaluations being made for both gas production and hydrocarbons. Information was submitted by interested leasees, numbering ten potential bidders. Comments have been requested and submitted from various groups within the community impacted by the leases. Public meetings have been held in Canary City to receive public input. A total of 75 written comments have been received, and a two-day hearing resulted in over 150 people being heard.

A final decision will be made after the lease sale hearing, which will be held in the near future.

G. Issues Raised As a Result of Scoping

The following issues were identified in the scoping process and are to be analyzed:

1. *Potential impacts to the commercial fishing industry.* The local economy is very dependent on commercial fishing, with many productive fisheries being located within the proposed lease area. Concerns have been expressed over damage to fishing grounds and to fishing gear by oil drilling and extraction operations.

2. *Potential impacts to the tourism industry, local economy, and visual resources.* Tourism is a leading local industry, and residents fear that oil drilling and extraction operations will lessen the desirability of the island as a tourist mecca, and that damage may occur to certain underwater features. Scuba diving is an important tourist activity around the island.

3. *Potential oil spills.* Concerns exist regarding oil spills, including: increased risk of oil spills, lack of effective oil spill cleanup and control equipment, lack of a local oil spill cleanup cooperative, restrictive weather conditions, and lack of a deep water harbor for access by oil tankers.

4. *Degradation of local air quality.* Many commenters fear that the current high level of

South Shore Canary Island Proposed Oil and Gas Lease (Cont.)

air quality will not be maintained, and that Canary City will suffer from lessened air quality.

5. *Degradation of local water quality.* Concerns have been expressed over degradation of present high water quality levels due to accidental oil spills and the discharge of drilling muds, cuttings, and formation waters. The current high water quality contributes to the high productivity and diversity of marine biological communities, tourism, and the valuable commercial fisheries.

6. *Conflicts with local land-use policies and activities, and the lack of existing infrastructure and support facilities.* Concerns have been expressed over the potential change to the offshore environment, and the need to build support facilities for the exploration teams and potential loading facilities for oil tankers.

7. *Potentially harmful effects to the sensitive marine life, including marine mammals, seabirds, fish, kelp, reef-dwelling species, and benthic organisms.*

8. *Potential dangers to offshore structures (platforms, pipelines, subsea completions, etc.) from geologic hazards such as mass transport, steep slopes or canyons, active faults, shallow gas deposits, or other geohazards.*

9. *Requiring the transportation of hydrocarbons by pipeline when feasible.*

H. Alternatives Identified

As a result of various forms of input, the following alternatives have been identified:

1. Offer blocks for sale in both the West and East Canary Island Basins.
2. No sale.
3. Offer only blocks in the West Canary Island Basin.
4. Offer only blocks in the East Canary Island Basin.

II. DEVELOPMENT ALTERNATIVES

A. Analysis of Alternatives

Alternative 1: Offer blocks for sale in both West and East Canary Island Basins

The development of both the East and West Canary Island Basins would involve the installation of offshore platforms in both basins and the installation of a common, onshore oil treating/pumping/pipeline system. In general, the development has been conceptually planned as outlined below, but it may have to be varied after commercial oil and gas reservoirs are actually discovered (development plans will vary with reservoir size, loca-

South Shore Canary Island Proposed Oil and Gas Lease (Cont.)

tion, oil characteristics, and recovery/production per well).

The following is a general description of the types of facilities necessary to produce a commercial discovery off the coast of Canary Island. The development plans are based on other offshore developments along the coast.

- *Installation of a self-contained offshore platform in the East Canary Island Basin.* The platform would be self-sufficient in supporting drilling operations, producing operations, and environmental/safety operations for developing the oil and gas found in the East Canary Island Basin .
- *Installation of a self-contained offshore platform in the West Canary Island Basin.* The platform would be self-sufficient in supporting drilling operations, producing operations, and environmental/safety operations for developing the oil and gas found in the West Canary Island Basin. It is anticipated that the water depth of a platform in the West Basin will be greater than in the East Basin.
- *Installation of a common onshore oil treating, storage and pipeline facility.* This facility would be located on Canary Island and requires more space than that which can be supported from an offshore platform. By sharing facilities, the two developments (East and West) would reduce the number of facilities needed to develop the oil and gas. The oil treating facilities may not be required and are solely dependent on the liquids (oil/water) produced. The common storage and pipeline system would marshal the oil to existing onshore pipeline networks for transportation of the oil to the onshore refineries.
- *A common environmental strategy for both developments would be developed.* The goal of this strategy would be to have uniform compliance of all oil and gas development with applicable federal, state and local regulations. The facilities could then be designed to meet air and water quality standards, etc., in a consistent manner with total impact being a consideration. In a similar manner, oil spill equipment and personnel could be shared by the overall development, with training and drills implemented to provide protection for the Canary Island area.
- *The facilities would be designed in a manner to allow them to be compatible with their surroundings.* This could include the same (or improved) means taken by other urban oil and gas developments. Specific measures, such as sound proofing, landscaping, and other construction techniques to make a development aesthetically pleasing to the surrounding community, could be taken.

Alternative 2: No sale of the blocks offshore Canary Island.

South Shore Canary Island Proposed Oil and Gas Lease (Cont.)

The area surrounding the Canary Island Basins is determined to be too sensitive to support an oil and gas development. The environment, with its many types of plant, seafloor, fish and animal life, together with the current community development, are viewed to be too sensitive to be put at risk to an oil and gas development.

Alternative 3: Offer blocks in the West Canary Island Basin.

The development of West Canary Island Basin would involve the installation of an offshore platform in the basin and the installation of an onshore oil treating/pumping/pipeline system. In general, the development has been conceptually planned as outlined below, but may have to be varied after the actual discovery of commercial oil and gas reservoirs (development plans will vary with reservoir size, location, oil characteristics and recovery/production per well).

The following is a general description of the types of facilities necessary to produce a commercial discovery off the west coast of Canary Island. The development plans are based on other offshore developments along the coast .

- *Installation of a self-contained offshore platform in the West Canary Island Basin.* The platform would be self-sufficient in supporting drilling operations, producing operations, and environmental/safety operations for developing the oil and gas found in the West Canary Island Basin. It is anticipated that the water depth of a platform in the West Basin will be greater than in the East Basin.
- *Installation of an onshore oil treating, storage and pipeline facility.* This facility would be located on Canary Island and requires more space than that which can be supported from an offshore platform. The oil treating facilities may not be required and are solely dependent on the liquids (oil/water) produced. The common storage and pipeline system would marshal the oil to existing onshore pipeline networks for transportation of the oil to the onshore refineries.
- *An environmental strategy for both developments would be required.* The goal of this strategy would be for the proposed and future oil and gas development to comply uniformly with applicable federal, state and local regulations. The facilities could then be designed to meet air, water, and other quality standards in a consistent manner, with total impact being a consideration. In a similar manner, oil spill equipment and personnel could be designed, taking into account future development. Additionally, training and drills implemented would provide protection for the Canary Island area.
- *The facilities would be designed in a manner that would allow them to be compatible with their surroundings.* This could include the same (or improved) means taken by other urban oil and gas developments. Specific measures such as sound proofing,

South Shore Canary Island Proposed Oil and Gas Lease (Cont.)

landscaping, and other construction techniques used to make a development aesthetically pleasing to the surrounding community, could be taken.

Alternative 4: Offer blocks in the East Canary Island Basin.

- *Installation of a self-contained offshore platform in the East Canary Island Basin.* The platform would be self-sufficient in supporting drilling operations, producing operations, and environmental/safety operations for developing the oil and gas found in the East Canary Island Basin .
- *Installation of an onshore oil treating, storage and pipeline facility.* This facility would be located on Canary Island and would require more space than that which can be supported from an offshore platform. The oil treating facilities may not be required and are solely dependent on the liquids (oil/water) produced. The common storage and pipeline system would marshal the oil to existing onshore pipeline networks to transport the oil to the onshore refineries.
- *An environmental strategy for both developments would be required.* The goal of this strategy would for the proposed and future oil and gas development to comply uniformly with applicable federal, state and local regulations. The facilities could then be designed to meet air, water and other quality standards in a consistent manner, with total impact being a consideration. In a similar manner, oil spill equipment and personnel could be designed, taking into account future development. Additionally, training and drills implemented would provide protection for the Canary Island area.
- *The facilities would be designed in a manner that would allow them to be compatible with their surroundings.* This could include the same (or improved) means taken by other urban oil and gas developments. Specific measures such as sound proofing, landscaping, and other construction techniques to make a development aesthetically pleasing to the surrounding community, could be taken.

III. DESCRIPTION OF THE AFFECTED ENVIRONMENT

A. Physical Environment

1. Geology and Petroleum Potential

South Shore Canary Island lies in an area with frequent tectonic activity due to its location close to the contact point between the Canary plate and the Pangaea plate. The Canary plate, on which the island is located, is moving northwest at a rate of 2-3 cm per year. The Pangaea plate, which abuts the Canary plate 20 kilometers to the southwest of the island, is moving southeast at a rate of 1-2 cm per year. The two plates intersect along the area known as the Santa Clara fault. Strike-slip faulting along the Santa Clara fault

South Shore Canary Island Proposed Oil and Gas Lease (Cont.)

causes frequent earthquakes. Its location under the ocean at this point indicates a potential for tsunami generation.

Historically, the part of the plate on which the island is located has been an accumulation zone for sediments for many millions of years, increasing its potential for containing hydrocarbons. The island itself is thought to be a remnant of the mainland. At this time, the island is located 35 kilometers west of the west coast of the mainland. Both the East and West Canary Island Basins are located in this zone.

As noted in Section I, the East Canary Island Basin test wells showed that the area has potential for containing hydrocarbons. While the extraction of these hydrocarbons was not economically feasible 20 years ago, the economic potential has increased with increasingly scarce sources left in the world. The West Canary Island Basin has shown an excellent potential for production of natural gas, and is thought by geologists to have hydrocarbon potential also, even though that potential was not discovered in the test wells drilled in the mid-seventies.

In summary, both basins show good potential for economically feasible production of gas and oil.

2. Geologic Hazards

Geologic hazards are defined as existing or potential geologic features or processes that could inhibit the safe exploration and development of oil and gas resources. Most geologic hazards are potential rather than continuous and active hazards. Potential geologic hazards which have been identified include a high incidence of seismicity, active faulting, mass transport of sediments, steep slopes (greater than 10 degrees), hydrocarbon seeps, shallow gas accumulations, and over-pressuring.

- *Seismicity.* The South Shore Canary Island site is located close to the Santa Clara Fault, which is the active boundary between the Canary Plate and the Pangaea Plate. The Santa Clara Fault is a strike slip fault along which creep is occurring regularly. Earthquake occurrence historically has been 1,037 recorded tremors in the 120 year period from 1874-1994. On the average, this area should experience one earthquake greater than Richter magnitude 5 every year, and one earthquake greater than Richter magnitude 6 every decade. Earthquakes with high Richter magnitudes have occurred in the area, and can be expected to occur in the future. Faults in the area are considered young, and therefore active.
- *Mass Transport.* Mass transport is the gravity-induced downslope movement of consolidated to semi-consolidated sediments. There is evidence for some mass transport of sediments along the south coast area of Canary Island. The shallower areas

South Shore Canary Island
Proposed Oil and Gas Lease (Cont.)

located within the proposed lease areas show no evidence of mass transport.

- *Hydrocarbon Seeps.* Hydrocarbon seeps are naturally occurring phenomena that may indicate weak zones that are potentially hazardous. Offshore hydrocarbon seeps in the South Shore Canary Island area are generally associated with shallow or active faults, shallow gas zones or exposed or thinly covered bedrock. Possible hydrocarbon seeps occur exclusively in water depths of less than 215 meters.

- *Shallow Gas Accumulations and Overpressuring.* No extensive shallow zones of confined gas have been found in the East Canary Island Basin. However, shallow gas zones are commonly associated with faulted and structurally complex zones in the West Canary Island Basin. Gas-charged sediments are zones of unconsolidated to semi-consolidated sediments, which are saturated with interstitial gas under normal to near-normal pressure. Decay of biogenic material is the primary source of this gas. Over-pressured gas in bubble phase can contribute to the instability of sediments by lowering the shear strength. Gas-charged sediments most commonly occur in extensive zones associated with seaward-dipping beds at shallow depth.

- *Tsunamis.* The occasional large earthquakes that are generated along fracture zones can generate tsunamis that affect the shallow regions of Canary Island. For example, the largest tsunami to strike Canary City was generated by the Excelsior earthquake of 1985, Richter magnitude 8.2. It produced waves up to 20 feet high that caused fifteen deaths and approximately $23 million in damages.

3. Non-Energy Mineral Resources

- *Sand and Gravel.* Most of the sand and gravel deposits surrounding Canary Island lie within the three-mile limit. There are no extensive deposits within federal jurisdiction.

- *Precious and Base Metals.* Due to the location of several producing gold mines on Canary Island, gold has been found in beach sediments in all areas of the island. It has been suggested that offshore gold accumulations may exist as large concentrates were produced from the Cenozoic deposits by wave erosion during the post glacial rise in sea level .

4. Physical Oceanography

The Canary Island area experiences surface-layer temperature variations from 7°C in the winter to 15°C in the summer. There are localized changes dependent on proximity to land and water depth.

- *Large-Scale Circulation.* The long-term average picture of Canary Island is that of a

South Shore Canary Island Proposed Oil and Gas Lease (Cont.)

broad (1000 m) and slow (10 cm/sec-1), current reaching at least to several hundred meters depth, which flows southward between late spring and fall and northward during the winter and early spring. Definitive studies are being made by the Coast Guard at this time, and will be ready for publication in 1995. Circulation is influenced by prevailing winds; Canary Island is located in the Prevailing Westerly wind belt. Changes in wind direction can occur due to low pressure systems which bring southerly winds, and to stationary high pressure systems over the interior landmass to the east, which can cause east winds.

- *Wave Conditions.* Wave height varies with weather conditions, as can be expected. Significant wave height is considered to be 4 meters. Seasonal variations occur with the May to October readings, showing that wave height exceeded 4 meters for an hour or more only four days a month, on the average. During the remaining months, November through April, the significant wave height exceeded 4 meters on 10 days per month.

5. Chemical Oceanography

Chemical factors considered include temperature, salinity, density, dissolved oxygen, pH, turbidity, and nutrients.

- *Temperature.* In addition to seasonal temperature variations mentioned above, thermoclinal temperatures also vary with the seasons. The winter and spring thermocline depth is 50 m or greater due to storm- and wind-related mixing, while summer thermocline depths may be as shallow as 10 m. In autumn, water column stratification may be strongest until the first storm arrives.
- *Salinity.* Salinity is subjected to the same physical parameters as temperature. In the absence of freshwater input, salinity varies minimally with the seasons. Surface salinities vary from about 33.0 to 33.6 ppt around the island. During the winter rains, runoff carried by the rivers entering the ocean from the island will reduce the salinity. Salinity also varies with depth. A range of as much as 3 ppt may be found during the winter over 30 m depth, while a summer depth range may be as small as 0.060 ppt over 70 m.
- *Dissolved Oxygen.* Offshore waters are generally saturated down to the thermocline with oxygen. Below this level, oxygen levels gradually decrease until a minimum is reached at 700-1000 m.
- *Acidity.* A pH of 7 is neutral, and normal sea water ranges from about 7.0 to 8.5. Lower values of pH may appear during times of extended runoff.
- *Turbidity.* Turbidity, or transparency, is measured with a Secchi disc. Secchi disc

readings indicate the amount of light that reaches a specific depth. Typical Secchi disc reading in coastal waters range from 2 to 10 m while open ocean values may reach 50 m. Readings show greater clarity in the summer months when there is little runoff, and lowered clarity during the winter rains.

- *Nutrients.* The major nutrients which characterize marine waters are nitrate, phosphate and silicate. These fluctuate with season and depth, the highest levels in the surface waters occurring during periods of low temperatures. Nitrate levels tend to be highest during the summer at all depths, decreasing (in descending order) during fall, winter and spring. Nitrate values also tend to increase with depth, since primary production is decreased below the photic zone. Phosphate and silicate levels follow similar trends, although silicate exhibits higher relative levels, since it is much less limiting due to its greater abundance and thus fluctuates seasonally to a much lesser extent.
- *Water Quality.* Water quality around Canary Island is generally excellent. Heavy metals, pesticides, petroleum hydrocarbons, and wastewater discharge products are noticeable problems in the areas with high population density nearby onshore.

7. Ocean Dumping

Ocean dumping has been, and remains, an accepted means of disposal of waste material from coastal states. There are 9 designated historic and active dump sites off the coast of Canary Island. Different materials are dumped at the different sites, including radioactive waste, industrial waste, toxic chemicals, and treated sewage. Prior to 1970, one of the sites was approved for disposal of low-level radioactive waste. Since such disposal was discontinued in 1970, the site has not been used. Low-level radioactive waste comprises tools, gloves, protective clothing, transport containers, and other articles which have been contaminated. The radioactivity of such waste averages less than one curie of activity per cubic foot of material. Contaminated material was usually placed in 100-liter (55-gallon) oil drums and completely surrounded with concrete.

The dump sites for other materials have permitted their disposal into the ocean with minimal pre-treatment.

8. Climate and Dispersion Meteorology

The climate of Canary Island is marine in character with cool, dry summers and mild wet winters. During the summer the area is dominated by the North Pacific Subtropical High Pressure System, which is then located to the west of the island. Dry, stable weather persists during the summer. During the winter, the Pacific High is considerably weaker and is located far to the south. The weather is then dominated by Pacific storm systems sweeping in from the west, resulting in frequent periods of cloudiness and precipitation .

Average annual precipitation on the island ranges from about 40 to 80 inches. About 90% of the annual rainfall occurs during the months of October through April. Temperatures are very moderate, with little variation between summer and winter and between day and night. In Canary City, the average maximum and minimum temperatures in January are 54°F and 41°F, respectively. In August, the average maximum and minimum temperatures are 61°F and 53°F, respectively. The highest temperature recorded is 85°F, while the lowest is 21°F.

In Canary City, cloudy skies are more predominant in the winter season. Cloudiness is frequent in the summer season as well, with fog or low cloudiness predominating in the night and morning hours, but clearing often occurs in the afternoon. Cloudy days are more common in winter, and most precipitation falls in winter. Visibility is often restricted by fog, especially in the months of September and October.

Wind data have been detailed elsewhere. Diurnal patterns show strong onshore winds developing in the early afternoon. During the night, winds reverse and tend to blow offshore. Some temperature inversions exist in the summer, increasing air pollution.

9. Air Quality

Air quality on and around Canary Island is generally good, with variations occurring in areas of high population density, and near the manufacturing and power plant areas. Pollution is mainly caused by lumbering activities, agricultural operations, and the fossil fuel burning power plant which supplies electricity for the island. Particulate emissions have been greatly reduced by modifying wood waste burning practices, by controlling dust from agricultural operations by the practice of no-tillage agriculture, and by reducing the use of pesticides. Generally speaking, the amount of existing pollution in the air is minimal, resulting in good air quality.

B. Biological Environment

1. Intertidal Benthos

Intertidal habitats are of two principal types: rocky and sandy. Gradations such as unstable boulders and human-constructed bulkheads, wharves, and breakwaters occur, but most of the island can be classified as either sandy or rocky.

The rocky shore intertidal substrate forms a stable platform to which macroalgae and invertebrates attach and obtain a firm hold against the force of waves. A myriad of invertebrates lives here, protected by the usually larger, attached (sessile) plants and animals.

South Shore Canary Island Proposed Oil and Gas Lease (Cont.)

Some attach to the larger basal organisms, while others move among the community, grazing on vegetation. Others filter small planktonic particles from the water, while others are predators of other community members. During high tide, while the intertidal is covered with water, fish feed on the productive intertidal community.

Factors which influence the distribution, abundance, and species composition of rocky intertidal shores may be divided into two categories: physical factors, and biological factors. The more important biological factors are competition and predation. Generally, the upper area contains some species which appear to be transitional between land and sea forms. These organisms can survive neither completely on land nor completely in the sea. The upper intertidal grades into the lower intertidal, which contains more and more species that occupy more and more of the available space until, somewhere around midlevel and below, every conceivable space is inhabited by algae or invertebrates. In general, the upper vertical limits of rocky shores are determined by physical conditions, while the lower vertical limits are controlled by the biological factors.

The environment of the exposed sandy intertidal is considerably less stable than that of the rocky intertidal. Every wave on a sandy intertidal beach moves large amounts of sand. Animals living on surf-swept rocky intertidal areas have solved the problem of wave shock by evolving powerful attachment devices or by living in cryptic habits. Organisms on surf-swept sandy beaches achieve the same solution by burrowing (burying) themselves in the sand. Nevertheless, sandy beaches have comparatively fewer organisms and species, and population level fluctuations are far greater.

The rocky intertidal area at Canary Island is found on the north shore and the eastern shore. Attached macro algae, barnacles, and mussels are found in both areas. Not all areas are equally sensitive to oil spills, with steep slopes less likely to become covered with oil than the flat areas or beaches. If an area should be obliterated by a catastrophe, recovery could come from drifting larvae or spores. The distance between the harmed area and brood stock would need to be close. Species which would have the most difficulty recolonizing such an area would be those which either brood their young, such as some seastars, or those which have very short dispersal distances, such as sponges, tunicates and many algae.

Sandy beaches are found along the west and south coasts of Canary Island. Due to the constant restructuring of beaches, the number of individuals per species varies greatly from year to year. There is, however, a characteristic group of animals which live just below the low tide line or within the sand between the tide lines. A few organisms, such as lice, live higher up on the beach in burrows or beneath organic debris. Economically important species of clams are found in this area. Oil from a spill could coat the beach temporarily, but the constant restructuring of the beach due to seasonal

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Proposed Oil and Gas Lease (Cont.)

changes in the wave patterns would cause the oil to be covered in subsequent years, as noted in the studies of the Santa Barbara spill in 1968.

2. Subtidal Benthos

Canary Island has a ringing shelf, similar to the continental shelf, which is cut by occasional canyons from rivers entering the ocean. The sediment grades from coarser sandy sediment in shallow water near shore to finer silt and clay substrates in the deeper waters near the outer margin. The benthic invertebrates similarly grade from filter or suspension feeders on sandy substrates to deposit feeders in finer sediments. Kelp forests anchored to a rocky substrate exist in abundance around the island.

Hard bottoms and topographic highs, such as seamounts, reefs, etc., are of great concern for offshore oil development because many of the rocky outcrops have high fish concentrations. Rocky outcrops have been found in all waters surrounding the island.

3. Fish and Shellfish Resources

Over 450 species of fish are found in the waters surrounding Canary Island. Large numbers of shellfish and other invertebrate species also occur in this area, with the most important being crabs, shrimp, bivalves, sea urchins and squid. These organisms support a thriving fishing industry for Canary Island. Although many of the fish and shellfish species are commercially or recreationally important, those which are not may be just as valuable, since they interact with those species which are of economic value. In addition, they may serve as food for, consume, or compete with economically important species. Also, species not now commercially important may become so in the future if new and/or improved techniques become available.

Important pelagic species occurring offshore include herring, northern anchovy, salmon, mackerel and albacore. Common offshore benthic species of species groups include hake, rockfishes, sablefish, lingcod and flatfishes. Important shellfish species include Dungeness crabs, shrimp, oysters, clams and other bivalves, sea urchins, squid, octopi, and abalone.

4. Marine Mammals

Canary Island is known for its variety of marine mammals, including at least 21 species of whales, dolphins, and porpoises (the cetaceans) together with 5 species of seals and sea lions (the pinnipeds) and the southern sea otter. The waters of Canary Island act as a meeting ground where populations of animals having different biogeographic affinities intermingle. Some of these species visit Canary Island on their migrations up and down the coast. Harbor porpoises and northern fur seals visit during the winter and early summer, while sea lions and northern elephant seals, bottlenose dolphins, and pilot whales visit during the late summer and autumn. Sea lions, harbor seals and harbor porpoises appear close to shore.

Pinnipeds constitute a conspicuous part of the marine mammal fauna of Canary Island. These include the Western sea lion, Stellar sea lion, northern fur seal, northern elephant seal, and harbor seal. Many of these species have breeding grounds on the island, particularly on the northern and eastern rocky shores.

Gray whales pass close to the island in their migratory paths to and from their breeding grounds to the south. They are found close to the island and range to as far as 15 kilometers west of the island. They also pass through the waters between the island and the mainland to the east. Pilot whales are found in the waters around the islands all year long.

Dolphins appear seasonally from June through October in large schools. The schools usually have newborn calves as part of the schools, suggesting that their calving areas are closeby. Dall's porpoises are frequently found near the island in areas where the water depth is around 100 fathoms. Killer whales have been sighted year-round near the island.

5. Marine and Coastal Birds

Canary Island contains a variety of foraging, resting and breeding areas for marine and coastal birds. Extensive research has been done by Canary College in studying the habitats and habits of these birds. Marine and coastal birds are found in all of the coastal areas of the island.

- *Seabirds.* Pelagic (open ocean) seabirds are the most conspicuous and numerous avian group found within the proposed lease area. This group consists of such species as shearwaters, petrels, murrelets, auklets and gulls. These seabirds exhibit a wide array of body forms, life history patterns, and strategies for obtaining food, reproducing, and avoiding predation. Different species utilize the open ocean to different degrees; some stay away from land throughout the year and come ashore only for a few months to nest and rear their young, while others feed briefly at sea but remain on land for most of the day. Seabird colonies are critical habitats, since reproduction and thus continuation of the species depends on these sites. For example, at these sites local populations are highly concentrated, reaching their annual high just after hatching. While seabirds may be able to avoid impacts from problems such as low food supplies, noise, or oil spills by simply flying away, for successful nesting they are limited to the area around the colony. The seabirds feed by seizing

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prey at the surface while flying, dipping just beneath the surface, and actively pursuing prey underwater to depths as great as 80 to 100 m. The diet and foraging areas of some species may be quite restrictive.

- *Coastal Birds.* A variety of coastal bird populations are found occupying the sandy beaches, rocky shores, offshore rocks and wetlands of Canary Island. Available habitat for these species has been reduced as the human population of Canary Island has increased. This has resulted in the loss of at least one important wetland habitat just north of Canary City. Heavy recreational use of the sandy beaches has reduced the value of these areas to coastal birds that forage and nest on Canary Island beaches. Species utilizing sandy beaches include the plovers, whimbrel, marbled godwit, sanderline, western sandpiper and the least sandpiper. Species impacted by loss of wetlands include the long-billed curlew and the western snowy plover. Coastal birds which utilize rocky shores and offshore rocks are provided with the most protected feeding and nesting areas. These species include the black oystercatcher, black turnstone, ruddy turnstone, spotted sandpiper, surfbird, and western gull. Common coastal species which may come into contact with OCS activities include herons, egrets and bitterns, shorebirds and waterfowl.

6. Threatened and Endangered Species

Threatened and endangered species are protected by the Endangered Species Act of 1973, and must be considered. Those which may be affected by activities resulting from the proposed lease sale include the gray whale, right whale, blue whale, fin whale, sei whale, humpback whale, sperm whale, loggerhead sea turtle, Canary brown pelican, peregrine falcon, bald eagle, short tailed albatross, Canary black rail, tidewater bogy, seaside bird's-beak, Thurber's reed grass and globose dune beetle.

7. Areas of Special Concern

Canary Island has two areas of special concern. One is the Canary Island Marine Life Sanctuary which was established in 1992 to preserve the offshore sealife which has proven to be such an attraction for scuba divers worldwide. This sanctuary is located on the northern and eastern shores of the island and extends offshore for a distance of 3 kilometers. It encompasses a wide variety of marine life for study and enjoyment. The other is the Canary Sea Otter Marine Refuge off the south shore of the island. Sea otters feed in this area extensively, and raise their young here.

C. Socioeconomic Environment

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1. Employment and Demographic Conditions

The total population of Canary Island is approximately 250,000 people, with the majority residing in Canary City. Canary City is the major urban area on the island, having a population of 175,000. The remaining 75,000 inhabitants live in the villages and towns spread all along the coast, with some farming the inland flat areas and low mountain slopes. Lumbering is an industry with limited potential due to the limited area of the island. The port of Canary City supports a significant fishing fleet, which includes commercial fishermen as well as sport fishing boats.

Tourism is an important industry on the island. Tourists visit the island not only to enjoy the splendid beaches on the west and south coasts, but to enjoy the remarkable marine sanctuary. The sanctuary is a haven for scuba divers from all over the world. The tourism industry has grown since 1965, and is one of the most important industries of the island.

Due to its moderate climate, Canary Island has in the last ten years experienced an increase in retired people coming to live there. It is anticipated that this will mean an increased need in health care facilities and services in the coming years, as the retirees age further. At this time these services are limited, with extensive facilities located on the main land.

2. Land Use

As mentioned above, the majority of the population is located in Canary City. The other small towns located on the island are mainly dedicated to farming and lumbering. As the island has become more and more of a tourist attraction, resorts have been developed on the south and west coasts. A small airport has been built to allow air travel between the island and the mainland. This airport services Canary City as well as the resort areas. Several campsites have been developed adjacent to the marine sanctuary. The remainder of the land area is agricultural, or open space. A considerable amount of coastal land is devoted to recreation and parkland.

The major land use concerns are: protection of natural resources (such as wetlands and onshore animal habitats), the safeguarding of resources needed to support the economic base of the communities (agriculture, fishing, forestry, tourism, and recreation), public access, and limiting the proliferation of unplanned urban growth. This is a particular concern due to the increase in retirees populating the area.

The island has an approved coastal plan, which was adopted in 1980. At that time a report was prepared, called "Canary Island Coastal Energy Impact Program;

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Development Scenarios and Siting Options". It evaluated the suitability of four sites for locating onshore facilities, such as a service base, a gas processing plant, or an oil and gas processing facility. Two of these sites were on the east and west sides of the island. Three were considered as potential sites for service bases, and one as a potential site for an onshore processing facility. None of the sites was deemed completely suitable by Canary Island in terms of meeting the industry's basic requirements for land, water depth, and services. Onshore facilities related to the development of offshore oil and gas development are not authorized under the existing coastal land use plan, except for onshore gas pipelines. The existing plan does allow for the modification of this policy through the amendment process, should the potential for offshore oil and gas development become a reality.

At this time, most of the coastline is undeveloped with the exception of Canary City and the resorts that have been built. Water supplies are limited, as local water is pumped from deep wells toward the center of the island. Canary City has built a tertiary sewage treatment plant, which receives sewage from houses and industries located in and near the city. The other small towns and rural areas have septic systems provided by the land owners. While there is adequate water for the existing population, an increase in demand may exceed the capacity of the existing water system.

Canary City has a navigable harbor at this time, but it is seriously crowded. It is the only port on the island, and serves both the commercial and recreational boats. There is room for 350 boats to be moored, and all berths are full. There is a public launching ramp, a boat building area, parking lots, a harbor office, and restrooms. Two boat repair facilities operate in the area, as do commercial businesses such as restaurants and marine supply stores. A commercial marina with slips for about 150 boats (mostly recreational) is located next to Canary Harbor.

The Canary Harbor District's navigable channel is 40 meters wide and is dredged to a depth of 5 meters. Water depths in the outer cove range from 4 meters to 30 meters. The harbor is busiest between May and October. During the peak summer period, over 550 vessels move in and out of the harbor on an average day. During the winter, about 10 vessel movements per day occur. The harbor is considered crowded.

3. Fisheries

There is a significant commercial fishery located in the proposed sale area. Over the last five-year period, the total commercial catch has increased from 8.9 percent to 18.1 percent for total pounds, and from 8.6 percent to 20.7 percent for dollar value. Annual variability in landings is due to many factors, including fish availability, market demand, weather conditions, and harvest regulations. The eleven species or species groups ranking highest in terms of total dollar value are Dungeness crab, Dover sole, rockfish, chinook salmon, sablefish, Pacific Ocean shrimp, albacore, petrale sole, English sole, rex sole, and Pacific hake. These eleven species represented over 90 percent of the total value landed in 1991 and 1992.

Spawning grounds for most of these eleven species overlap the proposed sale areas. The different species are fished using different techniques which will not be detailed here.

Over 100 species of fish representing 41 families are caught in the Canary Island area by sport fishermen. The most important species are blue rockfish, lingcod, striped bass, chinook and coho salmon, white croaker, jacksmelt, barred surfperch, redtail surfperch, yellowtail rockfish, black rockfish, shiner surfperch, vermilion rockfish and walleye surfperch. Sport fishing is an important recreational activity on Canary Island, and accounts for many of the tourists who come to the island.

4. Recreational Resources

Canary Island provides unique and diverse recreational opportunities, from the rugged rocky coasts to the sandy beaches. Tourists are attracted from all parts of the world to view the scenery and enjoy the solitude of its relatively pristine environment. The Marine Reserve attracts many tourists for skin diving, diving, tidepooling, fishing, snorkeling, and boating. In addition, whale watching, surfing, and wind surfing are enjoyed in all areas of the island. Most campgrounds and resort facilities are full during the peak vacationing times when the weather is favorable. This occurs mostly in spring, summer, and early fall. During the rainy season the number of tourists is reduced, but still significant.

The importance of tourism to the local economies cannot be overstated, with vacationers contributing approximately 39% to the total revenue of Canary City. In addition, the area attracts artists and artisans whose wares appeal to the tourists. Recreational boating is also significant, and fills all available moorings during the season.

5. Cultural Resources

While no archaeological findings have been made on Canary Island, it is suspected that the Native Americans who inhabited the mainland may have used the island as a fishing station. They made sea-going canoes, and possessed sufficient navigation skills to reach the island. No extensive searches have been initiated to find evidence of such stations.

There are several shipwrecks that have been located by divers in the waters off the

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south and west shores of the island. These shipwrecks are of historical interest, and are curiosities for divers, but do not seem to have any significant value. They have been surveyed, and descriptions are on record at the Canary Island Museum and Historical Society.

6. Refineries

At the present time there are no refineries located on Canary Island. The closest refineries are located on the mainland, 35 miles to the east. Oil produced from the Canary Island basins would be either piped to the mainland or shipped in tankers.

7. Marine Vessel Traffic

At this time there are no existing or proposed marine vessel traffic lanes in the immediate Canary Island area. Tankers access the mainland refineries through traffic lanes located about 20 miles to the east. Main traffic is confined to the vessels which operate out of Canary Harbor, and the pleasure boats which make the trip from the mainland.

8. Military Uses

At the present time, there are no military activities conducted in the area. Occasionally, flights from the naval air station on the mainland pass over the island, but not on a regular basis.

IV. ENVIRONMENTAL CONSEQUENCES

A. Basic Assumptions for Impact Analysis

This section summarizes the key assumptions upon which much of the impact analyses are based, and the potential generic impacting agents that are typically associated with offshore oil and gas projects.

1. Oil and Gas Resource Estimates

The oil and gas resources estimated for the proposed sale area are listed in the table below.

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Resource Estimates for Proposed Offshore Oil and Gas Lease Sale, Canary Island Basin Sites

	Barrels of Oil (in billions)	Cubic Feet of Gas (in trillions)
Base Case	0.40	0.82
High Case	0.79	1.49

2. Exploration and Development Assumptions

The proposed lease sale would lead to the exploration for and the potential development and production of offshore oil and gas resources. The steps leading up to the eventual production of oil and gas include pre-lease activities such as geophysical surveys and geological sampling programs designed to study the age, structure and hydrocarbon potential of the area. Post-lease activities include: 1) exploration (wildcat) wells drilled by the oil and gas industry on geologic structures which show the best hydrocarbon potential as suggested by the geological and geophysical data; 2) development platforms which produce oil and gas from those exploration programs that discover economically recoverable hydrocarbons; 3) the development of transportation facilities to carry the produced hydrocarbons out of the area for refining; and 4) support operations to provide the necessary materials, manpower, and equipment for the industry. Onshore support that may be required during the exploration phase includes docking, equipment storage, service facilities, helicopters and the attendant facilities. Additionally, during the development phase, offshore processing facilities and equipment and deep water tanker ports (marine terminals) may be needed as well as onshore support facilities. The following development assumptions were made:

1. No petroleum refineries are expected to be constructed on the island.
2. Pipelines would be constructed and tankers would be used to transport the crude oil to refineries.
3. Various effluents would be discharged into the sea during the normal, routine operations of the development program. These effluents include drilling muds and cuttings, formation waters, sewage and other wastes of various volumes and types.
4. Onshore facilities such as supply and crew boat bases, support facilities, and pipelines would be developed. Oil processing facilities to separate oil, gas, and water would be constructed offshore.

3. Oil Spills

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The Oil Spill Risk Analysis is based on numerous assumptions which are made solely for purposes of analysis. Results are therefore hypothetical, and reflect only what may happen, given the present level of knowledge for the area.

- *Oil Spill Risk Analysis Model Description.* Oil spills from offshore oil and gas activities can cause significant impacts to the environment. They can potentially impact resources ranging from biologically sensitive habitats and endangered species to recreational beaches or military operating areas. In the past ten years, oil spill accident rates from drilling platforms and pipelines have decreased. While it is possible that a damaging oil spill accident could occur, the probability is dependent upon the amount of oil being produced. There are natural seeps in the proposed lease area which could potentially release more oil than would be released during an oil spill. For the base case scenario, the mean number of large and very large spills estimated to occur as a result of the lease over a 25-year period is 1.40 and 0.64 respectively. For the high case scenario, the probability increases to that of a moderately likely event, with the estimated mean number of large spills increasing to 2.77 over the 25-year period.

- *Oil Spill Cleanup and Containment.* The prevention, containment and cleanup of oil spills has become a central area of concern for the oil industry, the regulators, and the general citizenry. Consequently, much research has been conducted to investigate the various factors that influence the causes, the environmental damage, and the cleanup techniques of oil spills. As a result, strict operational and environmental regulations along with improved drilling procedures and containment/cleanup techniques have been developed. The regulations specifically address blowout preventors, pollution prevention equipment, oil spill contingency planning, personnel training requirements and the maintenance of onsite oil spill containment and recovery equipment. These requirements apply both to exploratory as well as to development and production operations.

  Oil spill cleanup devices fall into several categories such as booms, offshore devices and the Vikoma Seapack for containment, skimmers, the Oil Mop and other cleanup equipment, sorbents, separators, and chemical dispersants. The use of equipment will be dictated by factors such as wind and sea state including currents, period of the waves, and the type of petroleum spilled. These variables must be considered in making a decision as to what cleanup alternative will be used. Detailed oil spill contingency plans will be required as part of the permitting process for exploration and development.

  The effect of the requirements and regulations noted has been to increase the capability of the onsite equipment to handle small spills. An industry funded oil spill cooperative operates in the waters off of the mainland.

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- *Effects on Marine Life.* Petroleum hydrocarbons may have both short- and long-term effects on marine organisms and habitats. Short-term effects (0-30 days) are associated with the immediate impact of spilled oil, while long-term effects may arise with chronic discharges of hydrocarbons or hydrocarbon contaminated materials. Short-term effects generally result in death to the organism or decimation to the habitat, while long-term effects may be sublethal in nature. The effect of spilled oil on biological systems is highly dependent on the type of oil and its physical and chemical properties, the forces that act on the oil upon exposure to the water and atmosphere, and the sensitivity of the organisms to hydrocarbon exposure.

5. Manmade Structures

Both onshore and offshore manmade structures will be introduced if the lease sale is granted. Onshore structures refer to shore and land facilities needed to support the proposed offshore hydrocarbon activities. These can include gas processing or treating facilities, supply and crew boat bases, onshore natural gas pipelines, temporary support bases for onshore and offshore pipeline installation activities, and airports for helicopter support activities. Direct, potential impact-producing agents resulting from these onshore manmade structures include space-use conflicts, air emissions, and temporary beach disturbance.

Offshore structures involve use of a drilling rig, support vessels, and helicopters. The exploratory operations are typically short-term, lasting approximately four months per well, per site. Direct, impact-producing agents of exploration are vessel anchorage, increased vessel traffic, drilling noise, vessel presence and drilling and operational discharge. Vessel presence may, in turn, result in navigational hazards, spatial preclusion of fishing activity, and viewshed disruption.

Development activity includes installation operations, offshore structures, and abandonment activities. Installation operations include installation of platforms and subsea pipeline installation. Platform installation typically takes about six months, while laying the pipeline takes about three weeks. Direct, impact-producing agents associated with pipeline laying are pipeline burial operations, explosion of rocky areas and abandoned buoys. Offshore structures include platforms, pipelines, single-anchor leg moorings, and subsea wellheads. Long-term activities include the actual presence of structures and their associated discharges and emissions. This presence can potentially lead to navigational hazards, viewshed disruption, spatial disruption (preemption of fishing space), navigation aids, and artificial habitat for marine organisms. Abandonment operations involve the use of bulk explosives to sever the platform support legs, pilings, and/or the exploratory well caisson about 15 feet below the seafloor. Platform materials from abandonments are typically transported ashore for salvage, but have occasionally also been used for offshore artificial reef material.

6. Vessel Traffic

Increase in vessel traffic would include that of oil tankers used to transport the oil, supply and crew boats used to service the platforms and transport equipment and crew, and research vessels used for geophysical survey operations.

7. Noise from OCS-Related Activities

Noise emissions are associated with the operation of offshore platforms, drilling rigs, seismic surveying, petroleum transfer facilities, onshore processing plants and pump stations (development and production phases only), aircraft, and vessels. Most noise would not be audible to those on shore, but could have a negative effect on the activities of marine organisms.

8. Effluents, Discharges, and Effects on the Marine Environment

- *Water.* Effluents consist of two types: those from normal or routine operations and those which are episodic in nature and are the result of human error or accidents, such as hydrocarbon spills from fuel transfers or machinery breakdowns. Routine effluents likely to be discharged are ballast water, cooling water, desalinization brine, excess cement, deck drainage, treated sewage, formation water, drilled cuttings and drilling fluids.

- *Effects on Marine Life.* Resuspended bottom sediments, drilling muds and cuttings, formation water, and discharged wastewater may all have impacts on marine biota. The effects on marine life from resuspended sediments resulting from pipeline laying or platform placement would primarily be through turbidity or smothering effects and, potentially, through toxicity effects from the resuspension of detrimental materials that had been incorporated within the sediments. The volume of routine effluent expected to be discharged is very small given the volume of ocean receiving the effluent and should present an insignificant impact in most areas.

  Sessile organisms within several meters of the activity could be buried, and benthic communities may change as a result of altered sediment parameters. Turbidity plumes might temporarily disrupt the normal behavior of zooplankton and fish in the area. The release of existing pollutants (such as metals and pesticides) back into the water column may occur in areas where coastal and offshore sediments have elevated levels of. pollutants.

  The extent of negative impacts on benthic species from platform settling and anchoring will vary depending on the type of platform and the number of wells drilled. Low impacts are expected because of the localized nature of the activity. Pipelines

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may disturb soft bottoms in an area 20 m wide along their axis. Pipelines traversing hard bottoms would cause disturbance of the same dimensions. The time required for the community to recover to its original population structure could range from one year for kelp to several years for mussels.

The toxicity of drilling mud has been debated among groups concerned with OCS-related impacts. The present data, although having shortcomings in several cases, indicate that muds have low toxicity when compared to petroleum hydrocarbons, trace metals in wastewater, or industrial wastes. Long-term study data tend to support the conclusion of low toxicity of muds, but some data indicate interference with growth in oysters and pecten clams at concentrations of 100 parts per million. The rapid dilution of drilling muds discharged reduce the toxic effects. Magnitude and direction of currents within the water column, as well as water depth, are important factors in increasing dispersion.

Approximately 90 percent of the releases of drilling muds and cuttings are transported toward the sea floor, with the remaining 10 percent dissipating within 1,000 m of the discharge site. The physical burial of non-mobile benthic organisms when drilling muds and cuttings are deposited directly beneath and very near the drilling rig has been shown to kill these organisms. In the case of production platforms, the communities within sediment bottoms probably will recolonize after a period of time; however, the colonizing species may not be those organisms characteristic of the surrounding areas. A significant interference in ecological relationships of the sea bottom ecosystem will occur within approximately a one-kilometer radius around the platform for a period of time lasting less than two years. The effects of routine discharges from oil and gas activities on the federal OCS may be mitigated to a large degree by alternate methods of handling these wastes in accordance with National Pollution and Discharge Elimination System (NPDES) permits.

- *Air.* Air emissions associated with offshore oil and gas development include nitrogen oxides, sulfur oxides, total suspended particulates, carbon monoxide, and volatile organic compounds. These are released during the exploration, development and production phases. During the exploration phase, emissions are produced by diesel engines used in drilling exploratory and delineation wells, crew and supply boats, and intermittent operations such as mud degassing and well testing. The development phase consists of the installation of platforms and pipelines, and drilling of development wells. During the development, emissions are associated with operation of support vessels, construction of pipelines, and construction of onshore gas processing facilities. Emissions at a platform during the production phase result from the operation of gas turbines, natural gas flares and vents, oil and gas processing, and fugitive emissions. Emissions also result from support vessels.

Onshore emissions can result from crew boats and supply boats operating in and near the support bases, as well as from vehicles carrying personnel and supplies to the support base. During production, onshore emission sources include support vessels, gas processing facilities, tanker unloading activities, and refineries.

Air quality stipulation should result in lower emission rates due to emission control technologies that would be required. The EPA has promulgated ambient air quality standards for certain pollutants. The question of possible effects of sulfur oxide and nitrogen oxide emissions on acid deposition is of concern because of the apparent link between such emissions in the industrial Midwest and East and the acid rain phenomena that has been observed in the eastern United States. A major study by Hidy and Young prepared for WEST Associates in 1986 (ERT Document No. P-D572-503) concluded that there is no scientific evidence for widespread regional environmental effects resulting from acid deposition in the western US.

9. Socioeconomic Assumptions

Potential socioeconomic impacts could result from oil and gas facilities and activities such as changes in employment opportunities, income, population, commercial fishing, recreational resources, land use, and public services and facilities. Impacts could also result from local expenditures of oil and gas companies or their representatives.

A study of the impact on coastal recreation and tourism was completed in 1986. The study suggests that while the number of trips to some locations may be reduced, there is an equivalent gain in other areas. The relationship between offshore structures and beach attendance was an important component of the study, however it proved inconclusive. The concept of beach attractiveness is very subjective. There is no knowledge of any actual reduction in tourism because of the presence of offshore structures in areas where OCS development exists. Although tourism brings added revenue to a community, there are negative impacts in the form of air pollution, traffic congestion and population growth.

10. Effects of the Physical Environment on Oil and Gas Operations

Geologic hazards are any geologic features or processes, existing or potential, that would inhibit the exploration and development of petroleum resources. Geologic hazards in the Canary Island area are a) areas of high seismic activity; b) active faults; c) mass transport of sediments; d) steep slopes; e) hydrocarbon seeps; and (f) shallow gas accumulation and overpressuring. Exploratory drilling operations will not be allowed within the potentially unstable portion of the lease block, unless or until the leasee has satisfactorily demonstrated to the Canary Island Regional Planning Area's Regional Director that mass movement of sediments is unlikely or that exploratory drilling operations, structures, casing, wellheads and pipelines can be safely designed to protect the environment in case such mass movement occurs at the proposed location. Permits for all platforms

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require a geological hazard survey similar to the exploration survey. The lease may be cancelled if it is determined that continued operation would pose serious harm to life or the environment. When a platform is in an area of recognized seismicity, all structures are required to be designed for an earthquake environment. Offshore pipelines must be designed to withstand numerous hazards during their lifetime.

The forces exerted by currents and waves are believed to pose no threat to the physical integrity of drilling rigs or production platforms used offshore of Canary Island. Bottom currents are not expected to affect the transportation of oil and gas by pipeline.

The coastal waters experience a high frequency of restricted visibilities due to thick fogs, which may occasionally restrict certain operations such as helicopter flights. Strong winds are infrequent, although in the winter season, occasional periods of strong winds and high waves may disrupt construction activities.

B. Interrelationship of the Proposed Lease Sale With Other Projects and Proposals

Adjacent to the lease sale areas are the Canary Island Marine Life Sanctuary and the Canary Sea Otter Marine Refuge, shown on the map on page 1. These two sanctuaries are protected by law, and operate within the three-mile limit.

Some tankers operate in the waters between Canary Island and the mainland, as noted above. Dump sites have been mentioned on the previous pages.

V. SUMMARY OF ENVIRONMENTAL IMPACTS

1. Physical Environment

Water quality will be affected by the effluents mentioned from construction as well as exploratory and development activities. The overall impact level of offshore operations on marine water quality arising from the proposed activity is expected to be moderate regionally and high locally in the vicinity of an oil spill. Impacts of air quality were estimated through computer simulation models. A small degree of air pollution can be expected in areas where activity is concentrated, but overall regional cumulative impacts would be low.

2. Biological Environment

The main impact to the intertidal areas would be from oil spills. The probability of oil spill occurrence in the area has already been discussed. Moderate or possibly high impacts on rocky outcrops immediately around a platform are possible from drilling operations. Regional impacts from drilling activities and pipelines are expected to be low. Oil

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spills, manmade structures, routine effluents and discharges, and noise may potentially impact fish and shellfish populations. The significance of such impact will depend on the number of fish populations affected, their size, and the magnitude and duration of the impacts.

There could be beneficial impacts on fish populations. Production platforms and probably other offshore structures act as artificial reefs that attract fish. Platforms could be used for mariculture operations. Mussels are commercially harvested from production platforms in some areas.

Noise from geophysical operations may temporarily affect fish populations. Noise and disturbances due to the operation of geophysical survey vessels, crew and support boats, drillships and helicopter overflights are potentially the most likely to affect marine mammals. But the main danger to marine mammals would come from oil spills. Cumulative impacts to most marine mammals are expected to be moderate. The same noise that affects marine mammals can be expected to affect marine and coastal birds. The main danger to these animals would come from accidental oil spills. Presence of toxins in effluent water may pose a threat to some birds, but is not considered to be of significant danger. Construction of onshore facilities may disturb nesting areas for some birds. Impact could be moderate for non-endangered species, and high for endangered species.

Wetlands are at risk due to onshore construction and possible oil spills. Oil spill recovery time for an estuarian environment is estimated to be two to five years. Oil spill probability is low, as discussed earlier.

3. Socioeconomic Environment

Any OCS exploration and development activities could result in changes in employment and population conditions on Canary Island, probably with increases in both. Both impacts are estimated to be high. Land would be needed to develop the onshore support facilities, and airport traffic could be expected to increase. Fisheries might be affected temporarily by exploration, but should hold steady at established rates after platforms go into production. Shellfish could be impacted the most. It is estimated that the impact would be moderate to low during peak years of activity. Sportfishing activities may be affected by oil spills, general vessel traffic, pipeline installation and operation of platforms. Impacts to sport fishing are expected to be low.

The biggest danger for all would come from the possibility of an oil spill. New remediation techniques are being developed and tested, and restrictions imposed by the EPA reduce the probability of an oil spill greatly. Economic losses due to an oil spill would vary depending on the size of the spill, the area affected, weather conditions, and the time of year.

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Marine traffic would be impacted by the presence of platforms and drill rigs which could be considered navigational hazards to other vessels under certain adverse conditions. Since the basins are not located along shipping lanes, this danger is low, and should have low impact.

This document is a summary of information regarding the South Coast Canary Island Site.

Disclaimer

The South Coast Canary Island Site is a fictional site located off the west coast of the U.S. mainland. It does not represent any existing area known to the author. Information contained in this document has been freely copied from the document Northern California Proposed Oil and Gas Lease Sale 91 - Draft Environmental Impact Statement, No. OCS EIS/EA MMS 87-0032, published by the Minerals Management Service of the U.S. Department of the Interior, December 1987.

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